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should be stencilled in black India ink in capitals and is enough for the necessary reduction. **Line drawings** should be drawn with black India ink on white paper. In ortho line drawings to be reasonably consistent with journal they should be double their intended final size and as such their width should be one of the following standard sizes: 135 mm for single width, 200 mm for 1½ column width, 280 mm for double column width. Lettering on the figures should be 11–4 mm high Helvetica Light 14° obtainable as tracer letters, is recommended. **Graphs** may be plotted on white or blue squared paper, grid lines that are to show the engraving should be inked in black.

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Abbreviations and Symbols Only abbreviations and symbols that have been generally accepted should be used. Unfamiliar abbreviations must be defined at first use.

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YEARS OF SERVICE – A review by the Editor

With the publication of Volume 51 *Acta Orthopaedica Scandinavica* celebrates its fiftieth anniversary, the first issue having been launched in 1930. Despite its fifty years the journal is still a newcomer in comparison with the age of the art and science of our speciality.

The Scandinavian orthopaedic service has since its inception in the nineteenth century been closely linked with the care of disabled persons and the management of bone and joint tuberculosis. Our speciality owes a great deal to the pioneers in the twenties who envisioned the future development of orthopaedic practice and research.

The foremost initiators and founders of the journal were Patrik Haglund and P. G. K. Bentzon who realized the need for an independent channel of communication separate from that of general surgery. The journal was founded in January 1930 at a meeting of eleven leading Scandinavian orthopaedists, "the great elephants", and all those present invested financially in the new venture. Patrik Haglund was elected Editor, P. G. K. Bentzon "redigenda curavit", managing editor, and an editorial committee consisting of two representatives from each of the four countries was formed. After the death of Patrik Haglund in 1937, P. G. K. Bentzon became the sole editor and continued progress was made under his guidance.

In 1947 Sten Friberg became editor and Sven Kjaer redigenda curavit, followed in 1948 by J. Agerholm Christensen. In 1950 Sophus von Rosen was elected redigenda curavit and he managed the journal throughout a period of flourishing development until his seventieth year.

Over the years the editorial and administrative structure was amended in accordance with developments. In the forties *Acta* came up against serious economic problems and after the financial state had been improved and stabilized the journal was adopted as the official publication of the Scandinavian Orthopaedic Association.

In 1971 the editorial structure was modified and its present form established. *Acta* is managed by an editor, an associate editor and a Scandinavian editorial board, which in 1978 was joined by an Icelandic member. The chairman of the board from 1970–1978 was Anders Langenskiöld and at the present time the chairman is Magnor Foss Hauge. The editors are supported by an editorial committee attended by specialist referees from the five participating nations.

From the beginning *Acta* has been published in close cooperation with Munksgaard International Publishers Ltd. At first articles were accepted in three languages, English, French and German, but since 1970 the official language has been English.

The volume of material for publication and the increasing costs led in 1976 to the change from single to double column typography and in 1978 from letterpress to offset printing. In addition to the regular journal issues *Acta* has

should indicate the subjects of the investigation. The abstract should comprise a brief and factual summary of the contents and conclusions of the paper, a pointer to any new information which it may contain and an indication of its relevance.

It should be presumed that the reader has some knowledge of the subject but has not read the paper. The abstract should therefore be intelligible in itself without reference to the paper. It should only in exceptional cases exceed 200 words.

Key words 4-9 key words for indexing should be given by the author(s) together with the abstract. They should be placed in alphabetical order and be in accordance with the Annual Bibliography of Orthopaedic Surgery (*J Bone Jt Surg* Boston Mass. USA).

Introduction This should be a brief outline of the nature of the problem with particular emphasis on the state of knowledge at the start of the investigation followed by a short description of the investigation itself and an outline of the reasons for publication.

Patients and Methods/Materials and Methods For clinical work dealing with patients the first heading will be preferred. The second is used in articles dealing with laboratory work or animal experiments.

Results This part of the paper provides a description of the results obtained (but neither a discussion nor a review of the literature). Double documentation in text and tables should be avoided.

Discussion The author is recommended to discuss, and not just recapitulate the results giving particular emphasis to unsettled and controversial points and pointing to some conclusion. No new findings should appear in this section.

Conclusion. In most articles a brief section summarizing conclusions of the work is appropriate.

Acknowledgements If applicable.

References References should be mentioned in the text by name of author(s) and year of publication. Citations in the text should appear as Smith & Jones (1960) or (Smith & Jones 1960). When there are three or more authors, cite their paper as *Doyle et al.* (1966). All authors cited and only these must be listed at the end of the paper in alphabetical order according to the name of the first author.

Examples

Lazcano M A, Anzel S H & Kelly P J (1961) Complete dislocation and subluxation of the acromioclavicular joint. *J Bone Jt Surg* 43-A, 379-392.

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In the jubilee year a multitude of questions remain unanswered and several areas of research are still untouched or have only recently begun to be explored. The field of surgical implants is still in a phase of investigation. The answer, if there is one, is still unknown. Only thorough studies combining biomechanical, physiological, technological and clinical considerations may provide that answer.

Whereas clinical studies in the past were mostly based on follow-up results, the future may offer even more reliable prospective studies – of course in accordance with the Helsinki II declaration.

It may be discussed whether or not cost-benefit studies are true science or research. Nevertheless, the limitation of the resources available to the health sector in the future will certainly also force orthopaedic surgeons to perform investigations with this aim, in order to define gains, losses and finally priorities. The ever growing geriatric section of the population is in focus in this respect.

The editorial board firmly believes that endeavours in the future will provide the answers to the multitude of questions still open and *Acta* will constantly aim to serve its readers with reliable guidance and true enrichment.

Knud Jansen

published separate supplements now totalling 180 in number. The supplements have been reserved primarily for academic studies and special topics.

The capacity of the journal has been growing steadily but this has been more than matched by the inflow of contributions. The policy has been to screen the papers more critically, rather than just expand the volumes, with the aim of securing a high scientific standard. In its fifty-year history the volumes of *Acta* have grown from 364 single column pages in 1930 to 808 double column pages in 1979 (corresponding to 1150 pages in the previous format).

The journal has had the pleasure of extending its boundaries and gaining increasing attention from readers and authors in Europe, USA, Japan and the Third World. In particular the group of subscribers in the USA and Japan is large and still growing. The total number of subscribers in 1939 was approximately 400 and today that number has increased tenfold.

The contents of the fifty volumes and the 180 supplements reflect the changing problems over the years and outline the trends in research and development both in Scandinavia and internationally. In the early period the problems related to "classic orthopaedics" predominated. Surgical tuberculosis, congenital dislocation of the hip, other congenital deformities and the aftermath of polio were the subjects in focus. With the eradication of polio with vaccination and the almost complete elimination of C.D.H. with early diagnosis and "preventive treatment" the picture changed greatly. Palliative and reconstructive treatment of acquired diseases became the topics of discussion. In the treatment of osteoarthritis: arthrodesis, hemiarthroplasty, osteotomy and recently total joint replacement have been introduced after encouraging follow-up studies. More recently the trends show an increasing interest in controversies and critical long-term studies.

The greatest impact on the image of *Acta* has been without doubt the inclusion of traumatology in orthopaedic practice and research. The classification and management of fractures and joint lesions, the results of conservative treatment and the various methods of fracture fixation have occupied considerable space in the journal. In both fields, elective orthopaedics and traumatology, recent trends indicate a growing awareness of the risks of treatment and a greater interest in long-term findings. Interest is also growing in the area of basic and experimental investigation. In this context, new tools and new procedures have opened up gates to new knowledge — scintigraphy, histochemistry, electronmicroscopy, and equipment for biomechanical research.

This is the state of affairs in 1980.

The present situation is the result of fruitful activity and the co-operation of several forces. Our predecessors on the board of *Acta* deserve our respect. Our collaborators and in particular our consultants deserve a word of gratitude for their qualified and faithful service with the aim of maintaining and raising the scientific level of the journal. We would also like to thank our contributors from all parts of the world for submitting their reports. They have provided a global picture of orthopaedic research — and the editor sincerely regrets that some articles even after revision must be rejected.

The advertising pages of the journal are an interesting section of *Acta*. We wish to thank the participating suppliers — also for their understanding of the limitations we feel are essential in the production of a scientific journal.

RACTURE HEALING

Concept of Competing Healing Factors

HULTH

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In the discussion concerning the theory of the healing of shaft fractures the demand for absolute stability of the fracture has been a dominating factor. This cannot be an absolute prerequisite because fractures of the tibia or femur heal well even with continued weight-bearing and movement. The ingrowth of vessels is apparently not a crucial factor. It is evident, however, that fractures caused by direct violence with soft tissue damage heal more slowly than fractures caused by indirect violence, irrespective of the treatment. Soft tissue heals with fibrous scar, fractures heal by bone regeneration. The author postulates that the damaged tissue stimulates (possibly via molecular determinants) the structural genes of undifferentiated cells to produce mRNA and proteins for either fibrous tissue or bone formation. The rate of healing of the fracture is determined by the degree of bone damage in relation to soft tissue damage. In fractures with extensive soft tissue injury there occurs a competitive condition in the common haematoma, with a risk of delayed fracture healing due to the dominance of cells that are triggered off by fibrous tissue formation.

Key words: bone healing, bone trauma, callus, fractures, fracture blastema, osteogenesis, osteosynthesis, soft tissue trauma, tibia fractures

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The methods of managing shaft fractures, particularly fractures of the tibial shaft, differ significantly. The methods are so divergent that one is tempted to ask whether the basis of fracture repair is understood. The older generations of surgeons, cited by Sir Watson-Jones (1952), thought like himself that stability such as that obtained by plaster immobilization without weight-bearing, was the only basis of good fracture healing. This union has deeply influenced our thinking and has dominated treatment in the earlier ages. When certain fractures did not heal well, many fracture surgeons became concerned with methods of still further increasing the stability of the fragments, and, above all, of hindering rotatory forces. The

ultimate stage has been the use of the rigid compression plates (AO or ASIF) by Swiss surgeons (Müller 1963).

The principal idea behind the "rigid stability hypothesis" has been the necessity to ensure proper vascularization of the fracture area. Representatives of the A.O. school claim that micromovements in the fracture cause the development of a fibrocartilaginous substance in the fracture region (Müller 1978). There are, however, shaft fractures which heal very well without any fixation of the fragments, e.g. femoral fractures in traction or humeral fractures treated with a simple bandage. The prerequisite in these cases seems to be the non-operative management of the fractures. Based on experience

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gained over the past 10 years or more many fractures of the tibia heal well when treated with long plasters and immediate weight-bearing (Dehne et al 1961) or even with short braces and early weight-bearing (Sarmiento 1967, 1974). Thus, the categorical statement of Watson-Jones is not correct. Many investigations show that in fact the healing of tibia fractures is more related to the manner in which the tibia was broken. Fractures caused by direct violence with extensive soft tissue damage take longer to heal than fractures caused by indirect rotatory or bending forces (Edwards 1965, Karlstrom & Olerud 1974, Thunold et al 1976). On the basis of the now abundant literature, Austin (1977) concludes that most fractures with a poor outcome belong to the high-energy group, irrespective of the treatment given.

If the slower healing of fractures with extensive soft tissue injury is due to a more difficult revascularization of the fragments, the results of open treatment with rigid plates (giving greater opportunity for the ingrowth of vessels), should give better results than conservative methods, but this is not the case (Karlstrom & Olerud 1974, Thunold et al 1976). One can therefore assert that the vessels are not the crucial factor in fractures. These vessels grow into the site even when this is exposed to movements. Another factor of greater importance must be involved, and therefore we need another hypothesis.

In the following, a hypothesis is presented which is called the concept of *competing healing factors*. Firstly, a few basic facts concerning the hypothesis are necessary.

1. Most wounds of soft tissue, such as muscles, fasciae and skin, heal by fibrous scars. Fractures of bone behave differently because a regenerate (or blastema), consisting of new bone, is formed during the fracture healing.
2. To heal a wound or a fracture, structural genes in the nuclei of poorly differentiated mesenchymal cells must be activated in order to produce the mRNAs and proteins

needed, and these must be of a different kind in wound and bone healing respectively. The activation of structural genes occurs thanks to specific molecules, probably derived from damaged tissue itself.

3. There is some experimental evidence that bone formation is not exclusively dependent on specific precursor cells (preosteoblasts), but that other differentiated, embryonic type or perhaps migratory (Trueta 1968, Ueda et al 1975), might contribute to bone formation. Here, we may compare Olerud (1978) determined osteogenic precursor cells (DOPC) and inducible osteogenic precursor cells (IOPC).

The transfer of the specific molecules to the damaged tissue to the undifferentiated cells might occur directly or indirectly through other cells, e.g. macrophages/osteoclasts. There is a hypothesis that young fibroblasts formed during wound healing, receive their formation from collagen breakdown products (Shekter et al 1976). The macrophages may be required to stimulate fibroblast proliferation in some as yet unidentified manner (Leibovich & Ross 1975). In the secondary osteons, e.g. those seen during bone remodeling in primary union of cortical bone, the osteoclasts are located at the blind end of the canal. Behind them are mesenchymal cells differentiating into osteoblasts (Shekter, Willenegger 1963, Olerud & Dander Lilliestrom 1971). Do the latter receive their formation from the osteoclasts? This question is justified in the light of the present knowledge of the function of the macrophages during antigenic challenge to the body. If the macrophages are able to digest and process the antigens, presenting this as an antigen-RNA complex to lymphocytes. Thus, the macrophages perform not only a scavenging function but also perform a delicate molecular-biological transfer. The essential factor in the hypothesis is not, however, the precise manner by which information from damaged tissue is transferred but that it occurs and is of

the initiation of repair. If this is accepted, it is much easier to explain hitherto obscure aspects of fracture healing, which the "stability hypothesis" is unable to do. Urist et al (1976) have shown the existence of the so-called BMP or bone morphogenetic polypeptide and this is exactly in line with the present hypothesis.

With the new hypothesis it is easy to understand the poorer healing of open fractures compared with closed fractures. In fractures with extensive soft tissue injury, competition may arise in the common haematoma between the specific molecules (determinants) for scar formation and bone formation. Should the former dominate, the wound-healing might prevent bone formation thus resulting in non-union. On the other hand, fractures with minor soft tissue injury heal more quickly because the undifferentiated cells are stimulated to produce the mRNA (and consequently the proteins) needed solely for bone matrix formation.

The greater the injury to the bone tissue in comparison with that of the soft tissue, the more rapid is the healing and *vice versa*. Longitudinal fractures of the tibia are good examples of a greater amount of bone than soft tissue damage and therefore these fractures heal rapidly. Careful soft tissue dissection at elective surgery, e.g. osteotomies, creates better healing conditions than rough incisions. Yet there is a greater risk of delayed healing of an osteotomy of the proximal tibia than in a closed fracture in the same region. Most operations for non-united fractures introduce new injury to the bone. Also, there is often an addition of bone as flaps and other grafts or a decortication, constituting the source of the release of bone determinants. On the other hand, rough incisions through soft tissue with crushed muscles e.g., in the case of plate osteotomy of fresh fractures might result in delayed healing because the twice injured soft tissue dominates over the bone damage. Due to the anatomical reduction with this method, the bone-forming space becomes limited to the little gap between the fragments the

entire external space is certainly dominated and filled up by scar-healing determinants. Rigid osteosynthesis becomes imperative in such invasive operations since movements let in abundant fibrous determinants and let out bone determinants. The "irritation callus" then occurs. In exactly reduced, conservatively treated spiral fractures, where the bone-forming space is fenced in by corticalis, the visible callus is often sparse though strong, owing to the absence of competition from fibrous determinants. In some cases, even a soft tissue incision for encircling wires, according to the cerclage method, is enough to result in disturbed healing.

Treating shaft fractures of the tibia or femur by weight-bearing plasters or braces causes rubbing of the fracture ends against each other which, in turn, releases bone determinants, whereas the soft tissues are "stabilized" to a sufficient degree. Open fractures with necrotic soft tissue debris (e.g. missile injuries) must be cleansed by debridement, since the debris makes use of the macrophages which might be crucial for the initiation of bone formation. Of course a still greater degree of competition occurs after bacterial contamination of the fracture wound. The mobilized cell apparatus (macrophages and leucocytes) is the same wherever the body is injured.

This hypothesis is based on known molecular-biological facts. To heal tissue damage, there must occur a transfer of information via molecular determinants from the damaged tissue to the poorly differentiated cells, the structural genes of which become activated in order to produce mRNA specific for tissue repair. Fractures caused by direct violence involve healing of both soft tissue damage and bone damage. In a common haematoma a competition between the two types of determinants occurs. This hypothesis provides another way of viewing fracture healing which makes it no longer merely a carpenter's affair. During fracture healing it is essential that a bone-forming blastema is allowed to develop undisturbed as much as possible, by fibrous scar-

formation. The risk of fibrous scar formation occurring is greater in open fractures or in the case of open fracture treatment with large incisions into crushed soft tissue. The risk of scar formation is reduced at elective surgery with anatomically made incisions in intact soft tissue. Generally, closed treatment of fractures is preferable because the chances of the formation of an undisturbed fracture blastema are greater, even with early weight bearing. Stability of a fracture is not a *conditio sine qua non*, but might promote bone-healing especially in compound fractures if the stability can be accomplished by non-invasive methods, e.g. transfixation by pins and plaster or by the Hoffman method (or Adrey Vidal).

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IN VIVO STUDIES OF BONE GRAFTS

The Possibility of Vascular Anastomoses in Healing Bone

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A titanium chamber enabling vital microscopic studies of bone tissue *in situ* was installed in the tibiae of 10 rabbits. Using a gentle surgical technique the chamber and surrounding bone were cut *en bloc*, twisted 360° and reinserted into the same donor bed. Vital microscopy of these orthotopical bone grafts revealed that the circulation was mainly regained via ingrowth of newly developed vessels of host origin, starting at 5-8 days after grafting. Bone remodelling was observed at 3 weeks post grafting in these cases. In two grafts, however, an additional mode of blood flow recovery was seen. Here vessels of more than 30 microns width, registered before grafting, apparently were functioning also afterwards, indicating end-to-end anastomoses between host and pre-existing graft vessels. In these two grafts bone remodelling started as early as 1 week after transplantation.

Key words: animal experiments, bone transplantation, *in vivo* studies, vascular anastomoses, bone remodelling

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A rapid re-establishment of the blood flow in bone grafts is beneficial for graft incorporation (Stringa 1957). The primary graft circulation is thought to be dependent either on the ingrowth of new vessels of host origin - *revascularization* - or on anastomoses between host and pre-existing graft vessels - *recirculation*.

Willenegger (1967) estimated the rate of the cutter head ingrowth to be 50-80 microns a day. On the basis of findings indicating that the necrotic border zone in the host bed is 0.5-1 mm wide (Rhinelander 1974, Albrektsson et al 1978), ingrowing vessels from the host bone would need a minimum of 6 days to reach the cortical graft tissue.

Revascularization

Most authorities agree that the blood circulation in bone grafts is dependent on *revascularization* (Burwell 1969, Albrektsson, 1971). The creeping substitution procedure is believed to be responsible for the primary *revascularization*, at least of cortical bone grafts, which is known to be slow. Schenk &

Recirculation

Recirculation has been suggested as a complementary possibility for the re-establishment of graft blood flow (Hancox 1947, Stringa 1957, Graf 1959, Zeiss et al. 1960, Deleu & Trueta 1965, Forgon & Bornemisza 1970, Albrektsson, B 1971, Olerud & Danckwardt-Lilliestrom 1971, Ray

1972) *Recirculation* was proved by vital microscopy to be possible in skin grafts (Birch & Bränemark 1969) but as far as bone grafts are concerned it is as yet a theory of uncertain validity. The assumption of *recirculation* in bone grafts is as a rule based on indirect observations of the vasculature during the first week after the transplantation. Some authors report a strikingly early appearance of blood vessels (Hancox 1947, Ray 1972), others a remarkable acceleration of the injectability of graft vessels from one day to another (Graf 1959, Deleu & Trueta 1965, Forgon & Bornemisza 1970).

Aims of the present study

Summarizing the opinions from the literature reviewed above, there is no true disagreement that revascularization is the important mode of re-establishment of graft blood flow. The debate has instead been focused on the following questions:

- 1 How fast is the revascularization process?
- 2 Is revascularization under favourable circumstances combined with recirculation?

The present article is an attempt to illustrate the early stages of autologous bone incorporation with specific emphasis on two questions.

MATERIALS AND METHODS

Ten adult male and female Belgian hares and lop-eared rabbits 9–14 months old and weighing 5–7 kilograms were used for vital microscopic studies. A bone chamber (Figure 1) was installed in the tibial metaphysis. The chamber type used in the present experimental series was partly unthreaded, but was in all other aspects the same as the type A chamber described by Albrektsson & Albrektsson (1978) in which paper the principles concerning the bone chamber method were presented.

During a healing period of 6–9 weeks vessels and bone tissue grew to fill out the chamber gap as seen in the enlarged part of Figure 1e. A Leica ESR and a Vinten scientific 16 mm camera were connected to a Leitz intravital microscope

allowing registration of the bone and vessel architecture of the 'future graft'. At grafting trephine was used, under flowing saline cooling, gently cut out the chamber with a surrounding bone collar. The graft-chamber complex was lifted out of the host bed, twisted 360° and returned to the same position as before grafting (Figure 1a). Graft stability was ensured by using a special constructed plate (Figure 1e). The animals were then scheduled for two examinations, one at 41 days after surgery and another at sacrifice which was planned at 12–15 days (5 animals) or 18–21 days (5 animals) post grafting.

The studied bone graft was regarded as 'fully vascularized' when the amount of vessels was the same as before grafting. Numerically this was defined by dividing the vessels into three groups: minor (<12 microns), intermediate (12–30 microns) and large (>30 microns) and measuring the added length of the vessels on anatomically performed drawings with the aid of a camcorder wheel pen. Bone surface area was calculated with a Teknor 95 planimeter.

During surgery and the vital microscope sessions the animals were under general anaesthesia maintained by i.m. injections of Hypnorm (Mecos, Helsingborg, Sweden) at a dose of 0.7 ml/kg body weight.

RESULTS

Definitions

Prior to grafting the differentiation between arteriolar and venular vessels could be made according to morphological characteristics and observations of the blood flow. In the first weeks after transplantation this was found to be difficult due to poor anatomical differentiation and irregular vascular arborization found in the repair tissue. Because of this the concepts minor, intermediate and major vessels – defined in the methods section of the present paper – are used in the text below.

The results from eight of the chamber grafts are presented together in Table 1, whereas two grafts are presented separately as the mode of vascular recurrence was different.

Table 1 Results from eight of the chamber grafts

Chamber no.	1	2	3	4	5	6	7	8
Animal sacrifice	II	II	II	II	III	III	III	III
Full vascularization	—	—	—	II	III	III	III	III
Bone accretion	—	—	—	—	—	III	III	III
Bone resorption	—	—	—	II	—	—	—	III

Period I 5-8 days Period II 12-15 days Period III 18-21 days

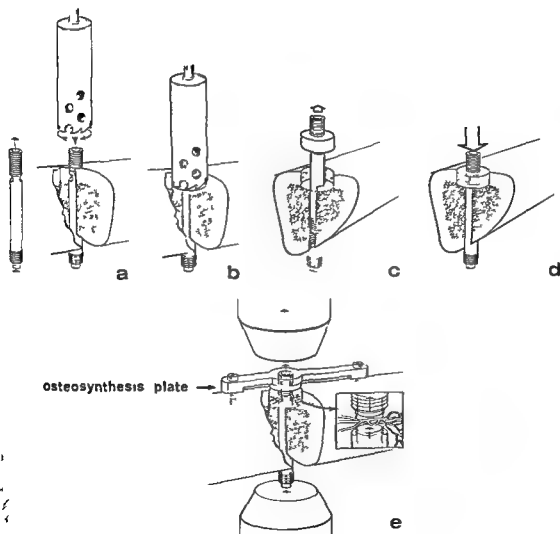


Figure 1
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 grafting

Primary vessels

All chamber grafts contained functioning vessels at 5–8 days post grafting. These vessels were always primarily confined to the connective tissue parts of the bone as illustrated in Figure 2. By calculating the length of the primary vessels and estimating the maximal capillary sprout penetration rate in cancellous bone to be about $\frac{1}{2}$ mm a day it was concluded that the observation area in two cases might have been invaded by the first vessels on day 4. The primary vessels were always of minor size growing in vascular arcs entering the observation field close to the point of leaving it. The vessels were tortuous with irregular and occasionally stagnant blood flow. The invading vessels seemed to penetrate the graft gradually by adding further vascular arcs on top of the old ones as indicated by the asterisk in Figure 2.

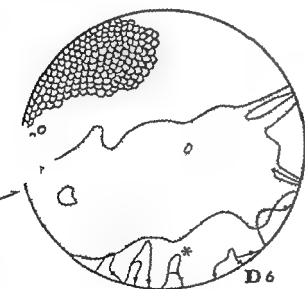


Figure 2 Drawing of chamber no. 2 6 days after the reinsertion procedure. The primary vessels with arrows indicating the flow direction are seen entering the connective tissue (white) in the observation field. These vessels gradually grow towards and into the bone tissue (dotted) during the following week. The asterisk indicates the typical vascular arcs seen in the early vascularization period. In the top left of the observation field a cluster of fat cells is seen.

Full vascularization

Three of the four chamber grafts observed at 12–15 days post grafting were not fully vascularized. The vessels found were less tortuous compared with those at 5–8 days post grafting. Most of the vessels were still minor in size although a few intermediate ones were seen. Vessels were observed not only in the connective tissue but also in the calcified parts of the observation field. The vascularization particularly in the bone parts of the graft was not as abundant as before grafting. One chamber at 14 days (Figure 3a,b) and all four chambers observed at 18–21 days post grafting were fully vascularized. Vessels of minor intermediate and large size were observed. There was no longer any vascular tortuosity to be seen. The blood flow was steady not slow or irregular. Even if there were as many vessels in the graft as before transplantation there was no resemblance between the original vascular architecture seen before grafting and that observed 1–3 weeks afterwards.

Bone remodelling

At 18–21 days post grafting in three chambers out of four new bone was laid down upon the original trabeculae observed before grafting. Bone accretion was always

Figure 3 In vivo colour photograph 14 days post grafting, of chamber no. 4 (3a) with an enlarged section (110 \times) shown in Figure 3b. The true diameter of the observation field is 2 mm. The minor spots seen especially in Figure 3b are osteocyte lacunae. Vessels of varying width are crossing the graft. Although the vessels are comparatively wide this short time after surgery they are newly developed vessels of host origin.

Figure 4 In vivo colour photograph 55 days post grafting of chamber no. 9 with an enlarged view (65 \times) shown in Figure 4b. The same graft is shown in the drawings Figure 5a,f. The new central vessels were also seen before grafting and it is concluded that these vascular channels are surviving because of end-to-end anastomoses.



b

limited to the very region of the old bone — in no case did bone formation occur without direct connection to previously calcified tissue. In one chamber bone resorption was evident in parts of the observation field at the same time as bone accretion was seen in another part. The chamber that was fully vascularized already at 14 days post grafting then showed evidence of ongoing bone resorption. The bone in this case covered an area 8 per cent less than that registered before grafting.

Evidence of recirculation

The two remaining chamber grafts behaved differently from the other eight studied. At the first observation after 7 and 8 days, respectively, the vascular architecture closely resembled the conditions before grafting. Some intermediate to large vessels seemed to be identical. By comparing pictures before and after grafting it was concluded that recirculation by end-to-end anastomoses must have occurred. One of the anastomosed rabbits unfortunately died for unknown reasons 11 days after transplantation. It was photographed 8 days after transplantation. The chamber bone was then already fully vascularized. Bone

had started and the bone surface was reduced by 6 per cent. There was no evidence of bone accretion. The other recirculation graft was not, as originally planned, sacrificed after 21 days. It was checked five times between 7 and 55 days post grafting (Figure 4a,b, 5a-f). Before grafting 77 per cent of the visible chamber area was occupied by bone and 23 per cent by connective tissue "islands". At 7 days there was evidence of both osteogenesis and resorption. At 27 days post transplantation the bone surface area occupied 49 per cent of

the observation field. Bone resorption had then reached its peak and osteogenesis became very dominant in the form of woven bone that later became lamellarized. At 55 days when the experiment was terminated the bone surface area occupied 55 per cent. The major vessels seen passing across the central field of the chamber bone slab before grafting were still recognizable 55 days afterwards. At 7 days it was noted that the blood flow was slow, occasionally stagnant. In these vessels, the diameter of which had increased from 30 microns before grafting to about 70 microns. With the exception of these major vessels the flow in other parts of the graft was principally indistinguishable from that before grafting.

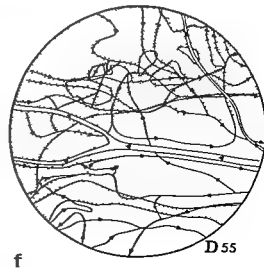
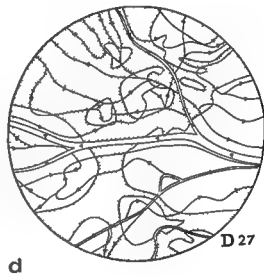
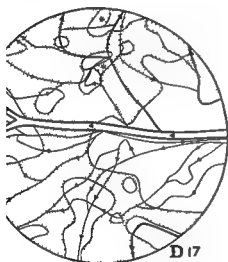
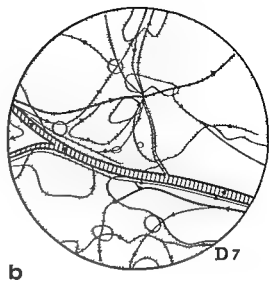
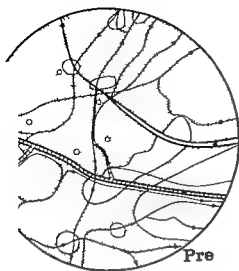
DISCUSSION

Revascularization and recirculation in grafted tissue

Most of the grafts described in this study regained blood flow via ingrowth of newly developed vessels — revascularization. As this mode of vascular penetration is described in many studies, the focus of the present discussion is aimed at the recirculation chamber.

Free grafted tissue is, by definition, deprived of its blood supply. The possibility of cell survival is dependent on the rapid return of the blood flow. Even if the graft cells primarily might be nourished through "plasma circulation" (Huebner 1893) it is generally agreed that regaining the blood flow is essential for normal cell function (Burke 1969). Numerous reports investigating the possibility of anastomoses in skin grafts have been published (cf Pihl & Weiber 1943; Zarem 1965; Marckmann 1966). Only by using a direct vital microscopic method (Birch & Brånemark 1969) was it possible to

Figure 5 Chamber no. 9 before and at intervals between 7 and 55 days post grafting. The major vessels seen before grafting are still recognizable 55 days later indicating end-to-end anastomoses. The vessels are crossed in Figures 5a and 5b to make comparisons easier. The beginnings of bone accretion can be seen in a small area in the left part of the chamber as early as 7 days, when also a more pronounced bone resorption is evident especially in the right part of the chamber. Bone tissue close dots. Woven bone and newly built lamellarized bone thin dots. Vessels with arrows indicate direction of flow.



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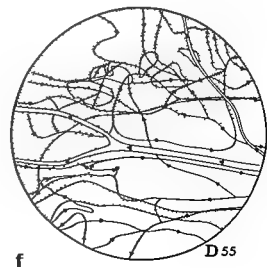
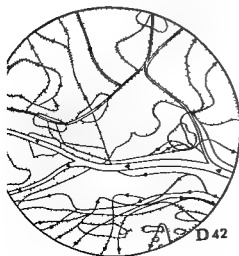
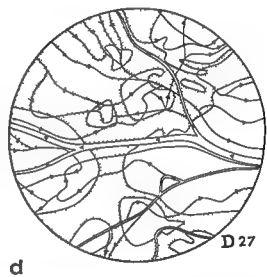
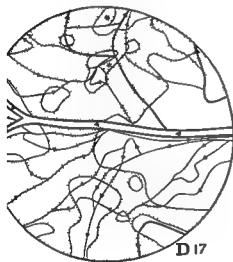
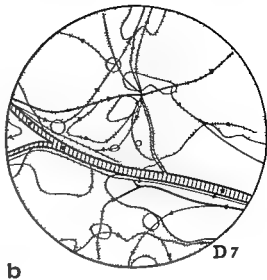
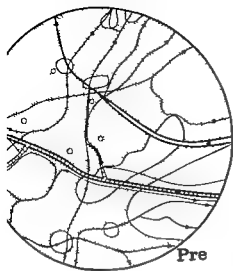
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reveal that the early circulation in skin grafts started 24–28 hours post grafting in pre-existing graft vascular channels. Comparing the data from the present article with those obtained by Birch & Bränemark (1969) some important differences are noted. Firstly, vascular anastomoses being a rule in free skin grafts (provided a gentle surgical technique is used) are an exception in the type of bone transplants described here. Secondly, the vascular architecture in the skin grafts rapidly underwent marked modifications completely changing the vital microscopic picture in a couple of days. The bone vascular picture is much more constant, probably due to the fact that the bone vessels, having to pierce the calcified tissue before establishing new connections are less apt to change their architecture.

Whether the vascular anastomoses described in this paper are actually bone-to-bone or rather marrow space-to-bone vessel connections is an interesting question to which at present no safe answer can be given.

Apart from the earlier mentioned reports about direct vascular connections in various types of grafts there are also critical studies claiming the improbability of end-to-end anastomoses (Zarem 1965, 1970). Even if the

cyte canaliculae do permit diffusion of tissue fluid, the calcified ground substance in bone acts as a barrier to the primary tissue fluid circulation (Ham 1952), further diminishing the chance for vascular anastomoses in this special tissue. It should indeed be kept in mind that what has been performed in the surgical procedure described in the present paper might be referred to as an osteotomy rather than an actual transplantation. In other recent studies where the graft was twisted 180° on transplantation or transferred to the contralateral bone (Albrektsson T 1979) revascularization always occurred via newly developed minor vessels of host origin. What it is believed is shown in the present study is that, under ideal conditions – i.e. control of the surgical trauma and immediate reinsertion of the graft

into the same position – a direct connection with re-established circulation between the vessels of host and graft origin is possible in bone tissue.

CONCLUSIONS

1 Re-establishment of blood flow in bone grafts occurs mainly by the process of *revascularization* – ingrowth of newly developed vessels of host origin.

2 Evidence is presented for the occurrence of *recirculation* – anastomoses between pre-existing graft and host vessels – under favourable circumstances.

3 In cases of *recirculation* bone remodelling was observed at 1 week after grafting whereas when *revascularization* occurred there was usually a delay of 3 weeks before observable bone remodelling.

ACKNOWLEDGEMENT

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INTRASOSEOUS PHLEBOGRAPHY, INTRASOSEOUS PRESSURE MEASUREMENTS AND ^{99m}TC-POLYPHOSPHATE SCINTIGRAPHY IN PATIENTS WITH VARIOUS PAINFUL CONDITIONS IN THE HIP AND KNEE

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Twenty five patients with pain in the knee or hip were examined by means

pain syndrome — showed venous stasis and increased pressure in the bone marrow near the painful joint and abnormally high uptake of the

engorgement pain syndrome in patients with a typical X-ray picture, increased isotope uptake in a joint region may be due to a variety of other causes. The identical findings with all three methods of investigation in patients with the intrasosseous engorgement pain syndrome and osteoarthritis suggest a common pathomechanism.

Key words: engorgement pain syndrome, intrasosseous phlebography, intrasosseous pressure, osteoarthritis

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In patients with painful osteoarthritis of the hip and knee the drainage of venous blood from the marrow of juxta-articular bone is impaired. Intrasosseous phlebography reveals a state of intrasosseous stasis (Mérle et al 1955, Phillips 1966, Arnoldi et al 1972a) and the pressure in the bone marrow is increased (Arlet et al 1968, Arnoldi et al 1972a, Lynch 1974).

Recently, Arnoldi and co-workers (1975) discovered that intrasosseous stasis and hypertension were more closely related to the symptom of rest pain than to the presence of osteoarthritic changes in the joint.

Based on findings from the knee joint Lemperg & Arnoldi (1978) described the *intrasosseous engorgement pain syndrome* and further experience has shown that the same syndrome occurs in the hip region.

These patients suffer from rest pain in the hip or knee areas, aggravated by physical activity. Anatomically, the joints are normal and X-ray examination reveals no signs of osteoarthritis. There is, however, in many cases a more or less marked osteoporosis of the joint bearing bone. The pain in the hip tends to spread towards the knee and the pain in the knee towards the lower leg. Intrasosseous phlebography always shows poor drainage from the bone marrow and the intrasosseous pressure is as a rule high. In our opinion

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ich region of interest are Poisson distributed, the standard deviation (S D) of the ratio (R) is

$$D = R \sqrt{\frac{1}{x} + \frac{1}{y}}$$

here x and y are the number of counts on either side

Measurements of intraosseous and intravenous pressure

These measurements were performed according to the methods described by Arnoldi and co-workers (1972a). The pressures were measured with the patient lying supine on a roentgen table with all anaesthesia was used. For examinations in the hip region conical cannulae with a lumen measuring 2.6 millimetres were introduced through the trochanter into the femoral neck. In the knee region the cannulae were inserted both in the femoral condyle and the proximal part of the tibia. All measurements were done bilaterally. The cannulae were flushed with a heparin-saline solution and connected to the pressure recording system by means of liquid filled tubes. Except for the brief periods of pressure recording saline flowed slowly through the tubes into the bone marrow with the saline infusion bottle at 150 cm above heart level. Unilateral measurements of venous pressure were obtained by means of a tube introduced into the internal saphenous vein in the ankle. In patients examined for intraosseous pressure of the femoral neck the tip of the intravenous tube was placed in the distal internal iliac vein, for measurement in the knee region the tip was placed at the level of the knee joint.

All intraosseous and venous pressures were referred to heart level. This was arbitrarily fixed at the midaxillary plane at the level of the fourth costal insertion on the sternum.

With intact arterial inflow to the bone marrow the intramedullary pressure is largely dependent upon the pressure in the draining extraosseous vein and varies with this pressure (Arnoldi & Linderholm 1971, Arnoldi & Linderholm 1972). The values of intraosseous pressure in this study are therefore given as the difference between venous and intraosseous pressure in mmHg (Figure 5). In measurements around the knee joint the highest pressure, either from the distal femur or from the proximal tibia, was chosen as representative (Arnoldi et al 1975).

Intraosseous phlebography

When the measurements of intraosseous pressure were finished 10 ml of water-soluble contrast medium Isopaque-Amin® was injected

into the bone marrow through the wide bore cannulae used for pressure measurements. The injections were performed bilaterally and simultaneously. The injection time was 20–40 seconds. Focus-film distance was 125 cm. The films were exposed at 60 to 70 kV and 640 mA with an exposure time of 0.40 s. The first exposure was made immediately after the injection of contrast. Further exposures were made at fixed intervals, the last being 30 minutes after the injection.

In the bone marrow of healthy joints the contrast medium disappears rapidly into the extraosseous veins (Arnoldi et al 1972a) while in painful osteoarthritis, and in patients suffering from the intraosseous engorgement-pain syndrome intramedullary retention of contrast is characteristic. A clearance time of 11 minutes or less was considered normal for intraosseous contrast (Arnoldi et al 1972a).

In addition, the intraosseous distribution of contrast was noted. Normally, the contrast passes directly from the tip of the cannula to the extraosseous vein and filling of intraosseous veins or sinusoids is only seen in a very limited area around the tip. In patients with painful osteoarthritis or intraosseous engorgement-pain syndrome the impaired drainage across the cortex results in an abnormal filling of large parts of the intraosseous veins of the region and in extreme cases the entire venous system of the marrow of a long bone can be observed. Thus, phlebograms with extensive intraosseous contrast filling, and delayed emptying (clearance time longer than 6 minutes) were considered abnormal (Figures 6 and 7).

FINDINGS

A Patients suffering from typical rest pain

Patients with osteoarthritis of the hip or knee joint, n = 10. Table 1 shows the results of the various examinations in 10 patients suffering from severe rest pain and osteoarthritis of the hip or knee joints.

As shown in Table 1 severe painful osteoarthritis in the hip or knee was always accompanied by intramedullary venous stasis. The intraosseous pressure was always higher on the affected side than in the bone marrow of normal joints. In unilateral cases the mean pressure difference was 29.4 mm Hg (range

(Arnoldi et al 1975) the intraosseous hypertension is the pain-triggering factor in these patients. High intraosseous pressure is lowered when the cortical wall is broken, either by an osteotomy or by fenestration of the cortex and the typical rest pain disappears promptly after these interventions (Arnoldi et al 1971, Åstrom 1975).

When using ^{99m}Tc -Technetium-labelled phosphate compounds for bone scintigraphy osteoarthritic joints are likely to show an increased uptake of various degrees at all stages of this disease (Hoffer & Genant 1976, Subramanian & McAfee 1971). Scintigraphy with these short-lived radiotracers is a painless and non-invasive examination, while intraosseous pressure measurements and phlebography usually have to be performed during full anaesthesia and the necessary intraosseous injections may cause unwarranted complications (Lempert & Arnoldi 1978).

The main purpose of the present study was to examine the usefulness of bone scintigraphy with ^{99m}Tc -Polyphosphate (Tc-PP) in the diagnosis of the intraosseous engorgement-pain syndrome and to compare the findings of scintigraphy with the results of pressure measurements and intraosseous phlebography. It was further hoped that these studies might throw some light upon the relationship between this syndrome and osteoarthritis.

PATIENTS

Twenty-five patients, 15 men and 10 women, with a mean age of 50.2 (range 25–75) years were examined in the present study. Seventeen patients suffered from typical rest pain around the knee or hip joint, i.e. a dull aching or throbbing pain felt diffusely around the joint usually increasing towards the end of the day and persisting at rest (Arnoldi et al 1972a, Heial 1965). These 17 patients either suffered from severe osteoarthritis of the hip or knee (10 patients) or fulfilled the criteria for the 'intraosseous engorgement-pain syndrome' (Lempert & Arnoldi 1978) (7 patients).

In the remaining eight patients the pain had a different character, either pain on loading or in-

termittent periods of sharp pain in the joint combined with locking of the joint. These patients were never present when the joint was examined at rest.

METHODS

The patients were subjected to the following examinations:

- 1 X-ray examination of the hip and knee joints.
- 2 Scintigraphic examination of the lower limbs including the pelvis.
- 3 Measurement of intraosseous pressure of femoral neck or the bones around the knee joint combined with measurement of pressure in the internal iliac or internal saphenous veins.
- 4 Intraosseous phlebography of the hip or knee joint.

X-ray examination

Both hips and both knees were examined with the patient standing. Frontal and lateral exposures were performed on all four joints, and the knee joints were further exposed in forced varus and valgus.

Scintigraphy

Twelve mCi of Tc-PP was administered 4 hours before the patient was examined using a 1-inch dual probe whole-body rectilinear scanner ('Elicint'). The collimators used had an almost depth independent response over the range of 10 inches, and joint regions were examined in positions symmetrical to the collimator. Scintigraphies were studied visually, photorecordings and in the corresponding video display processing (the latter was all done on a tape). The positive finding dealt with below is an increased osseous tracer uptake in the patellar region assessed by visual study of the scintigraphy (Figures 1 and 3).

In cases with unilaterally positive scintigraphic findings, the visual assessment of the scintigraphy was supplemented by a numerical assessment.

On the video display unit rectangular regions of interest were set to frame the whole joint region in a pair of joints. In anatomical size these regions of interest corresponded to a 9×10.5 cm rectangle around a knee joint region and a 6×6 cm rectangle around a hip joint region. The count rate between the affected and normal sides was calculated from the number of counts in each region of a pair of joints. Assuming the count rate

A Patients with unilateral rest pain

age mean and (range)	men	women	hip	knee	phlebogram		intraosseous pressure mmHg mean and (range)		scintigraphy	
					affected joint norm/ abn	normal joint norm/ abn	affected joint	normal joint	affected joint norm/ inc	normal joint norm/ inc
49.0 (33-69)	3	1	0	4	0/4	3/1	40.3 (25-59)	16.0 (13-19)	0/4	4/0

B Patients with bilateral rest pain

age mean (range)	men	women	hip	knee	phlebogram		intraosseous pressure mmHg (range)		scintigraphy	
					affected joint norm/ abn	normal joint norm/ abn	affected joint	normal joint	affected joint norm/ inc	normal joint norm/ inc
46.7 (25-58)	1	2	1	2	1/5	-	41.3 (32-47)	-	1/5	-

1 number of patients. norm—normal abn—abnormal inc increased

* clearance time > 6 minutes distribution of contrast normal

** clearance time < 6 minutes distribution of contrast normal



Figure 3 X ray picture of a hip with intraosseous engorgement pain syndrome taken after fenestration.

the unaffected joint was 24.3 mmHg (range 6-41). In one case the clearance time of a painless joint was longer than 6 minutes. Thus it was classed as abnormal although the area of bone marrow filled with contrast was small. The scintigram of the painful joint



Figure 4 Tc-PP scintigram of the same patient before the fenestration operation.

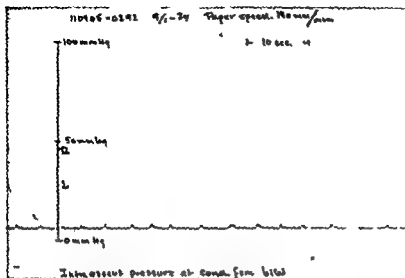


Figure 5 Pressure tracings from the internal saphenous vein at the knee level and from the knee marrow of the right and left femoral condyles. The patient suffered from the intraosseous engorgement pain syndrome in the right knee region.

always showed increased tracer uptake (Figures 3 and 4).

Numerical assessment of the scintigrams

The results of a numerical assessment of the Tc-PP uptake in the cases of unilateral

affection As described in "Methods" a ratio between the affected and normal hip or knee joint region was calculated (A). Among the 10 patients with osteoarthritis a unilateral affection of a hip joint or a knee joint was seen in two and four patients, respectively. Ratios and standard deviations in the form

Table 3 Findings in eight patients with miscellaneous painful joint diseases without rest pain (in total by means of bilateral intraosseous phlebography measurements of intraosseous pressure and Tc PP scintigraphy)

A Unilateral cases

n	age mean and (range)	men	women	hip	knee	phlebogram		intraosseous pressure mmHg mean and (range)		scintigraphy	
						affected joint norm/abn	normal joint norm/abn	affected joint	normal joint	affected joint norm/abn	normal joint norm/abn
7	45.0 (28-55)	4	3	2	5	3/4	7/0	21.3 (8-32)	22.4 (8-32)	3/4	6/1

B Bilateral cases

1	60	1	0	0	1	2/0	-	26 (25-27)	-	2/0	-
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n = number of patients norm = normal abn = abnormal inc = increased

Figure 6 Intraosseous phlebogram from a normal pain free knee. The cannula is placed in the tibial metaphysis and the exposure made immediately after injection of 10 ml of contrast medium. The contrast is seen in the extraosseous draining vessels. Filling of intraosseous vessels is observed in a small area around the tip of the cannula.



Figure 7 Intraosseous phlebogram of a patient with intraosseous engorgement pain syndrome obtained immediately after injection of 10 ml of contrast medium. The contrast is observed in intraosseous vessels in the proximal part of the tibia. Drainage in extraosseous veins is not seen (cf Figure 6).

group were 2.39 ± 0.24 and 1.30 ± 0.06 , and in the latter group 1.68 ± 0.11 , 2.17 ± 0.04 , 2.2 ± 0.04 , and 1.37 ± 0.04 (B). Among the seven patients with intraosseous engorgement pain syndrome a unilateral infection was seen in four patients, in all of them it was located in the knee joint. Ratios and standard deviations were 1.23 ± 0.01 , 1.26 ± 0.05 , 1.23 ± 0.06 , and 1.59 ± 0.05 . It is seen that (a) the individual ratios were measured with an accuracy greater than 10 per cent, (b) that count ratios tended to be higher in the osteoarthritic cases (in hip joints and knee joints with a mean of 1.85 and 1.61, respectively), than in the engorgement-pain syndrome cases (mean 1.33).

Patients with other types of pain in the hip or knee region, n=8

Eight patients suffering from other types of pain in the knee and hip region were examined in a similar manner. Four suffered from intermittent sharp pain combined with locking of the knee. The diagnosis in three cases was a torn meniscus, and in one case a loose body in the knee. One patient was found to have an old partial rupture of the lateral collateral ligament with pain on walking that disappeared after physical therapy. One patient suffered pain on loading

in the right hip due to secondary osteoarthritis after a tuberculous infection. Another patient with moderate pains of the same type had a roentgenologically severe unilateral osteoarthritis. The last patient complained of intense pain in both knees on loading. No reason for this was detected while he was in our care.

Table 3 shows the findings in this group.

Of the seven patients with unilateral pain, three (all with torn menisci) showed abnormal phlebograms. The pressures were normal. The scintigrams showed increased uptake in the same three patients and in one of the apparently normal and painless knee joints. The findings in the patient with bilateral pain were completely normal.

DISCUSSION

The techniques for intraosseous phlebography and pressure measurements used in this study have been described in detail in previous publications (Arnoldi & Linderholm 1971, Arnoldi et al 1972a, Arnoldi et al 1972b). An extensive analysis of the reliability and reproducibility of intraosseous pressure measurements has been published by Lempert & Arnoldi (1978) and the same authors discussed the relationship

between rest pain, delayed clearance of intraosseous contrast and intraosseous pressure. They concluded that intraosseous venous stasis seemed to be a constant finding in patients with rest pain. In patients with rest pain in the hip or knee the intraosseous pressure is higher on the painful side, but there does not seem to be a clear demarcation between normal and pathological pressure. Increased intraosseous pressure is probably the mechanism that triggers the pain sensation, but the threshold for pain varies from patient to patient.

The findings in the present study confirm earlier observations that patients with painful osteoarthritis always show impaired venous drainage from the marrow of juxta-articular bone. They also confirm that the same vascular disturbances may be present in the bone marrow of patients with rest pain but without clinical or roentgenological signs of osteoarthritis (the engorgement-pain syndrome).

Tc-PP scanning as a diagnostic method in patients with the intraosseous engorgement-pain syndrome

In patients with osteoarthritis of the hip joint accompanied by rest pain osteotomy or cortical fenestration is followed by an immediate fall of intraosseous pressure and relief of pain (Arnoldi et al 1971). Recently, Åström (1975) and Hietala & Åström (1977) showed that fenestration had the same effect on intraosseous pressure and pain in patients with osteoarthritis of the knee joint and in patients with the intraosseous engorgement-pain syndrome in this region. At the moment surgery is the only known effective therapy for patients with the intraosseous engorgement-pain syndrome and the only means of reaching a correct diagnosis are intraosseous phlebography and pressure measurements, time consuming procedures that demand full anaesthesia and intraosseous injections with the risk of bone marrow infection.

In this study Tc-PP scanning consistently showed increased uptake over joints with intraosseous stasis and hypertension, independent of the presence or absence of osteoarthritis. These results indicate that Tc-scanning can be used as a screening method for impaired venous drainage from juxta-articular bone marrow. A negative scintigraphy means that it is highly probable that a sensation of pain in the knee or hip is caused by intraosseous engorgement and hypertension. Increased tracer uptake and a typical history implies the presence of the intraosseous engorgement-pain syndrome. However, a positive scintigram is a nonspecific reaction and if surgical intervention is considered the diagnosis should be first verified by means of intraosseous phlebography.

The relationship between osteoarthritis and the intraosseous engorgement-pain syndrome

Intraosseous stasis and hypertension, observed in patients with painful osteoarthritis as well as in patients with the intraosseous engorgement-pain syndrome, seem to be caused by a blockage of the normal drainage vessels somewhere near the cortex. The mechanism is not known at present. However, investigations on the hip joint in patients with osteoarthritis indicate that the normal drainage vessels from the femoral head, the intracapsular retinacular veins, can be compressed by high intra-articular pressure caused by synovitis (Arnoldi & Reiman to be published).

High resistance to flow in the bone marrow reduces the nutritive capillary flow (Arnoldi et al 1971, Hernborg 1969) and it is probable that this circulatory derangement that is responsible for the characteristic changes in cancellous bone in osteoarthritis, such as the alternating zones of bone necrosis and osteogenesis described by Harrison et al (1967). This assumption is supported by the findings of Brookes & Heled (1968) who ligated the femoral and internal iliac arteries.

rats and observed a coarsening of the trabeculation and increased radiodensity of the femur. In patients with a history of severe incompetence of the venous pump of the calf and intermittent hypertension in the ankle region, Arnoldi et al (1972b) observed characteristic skeletal changes with apposition of new layers of bone in the cortex and a mixture of osteoporosis and sclerosis of the lamellae of the trabecular bone.

The findings by Tc-PP scanning were identical in patients with painful osteoarthritis and the intraosseous engorgement-pain syndrome. Recently, Bach Christensen & Arnoldi (in press) observed by means of autoradiographical and histochemical analyses of the osteoarthritic femoral head and the synovial membrane that ^{99m}Tc -phosphate accumulated in areas of new bone formation, especially in immature newly formed bone, while the uptake in the synovium was minimal.

The findings mentioned in this section may indicate that intraosseous stasis is induced by blockage of extraosseous intracapsular drainage vessels. Changes in skeletal metabolism follow as a result of impaired nutritive flow. One of the results of this disturbance — new bone formation — is noted on the Tc-PP scan long before it can be seen, for instance as osteophytes, on the X-ray. Thus, there is some evidence that the intraosseous engorgement-pain syndrome and osteoarthritis may be two stages of the same pathological process.

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THE EFFECT OF THE THICKNESS OF THE CORTICAL BONE ON BONE FORMATION BY OSTEOPERIOSTEAL GRAFTS

A Comparative Study Employing Routine Histological Stains and Triple Fluorochrome Labelling

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The bone-forming capacity of free periosteum was compared with that of 100 µm thick osteoperiosteum and periosteum with full thickness cortex taken from the tibia of 6-week-old rabbits. Altogether 78 rabbits were operated on

The results revealed that the osteogenic capacity of free periosteum and 100 µm thick osteoperiosteum was about the same, and that osteoperiosteum with full thickness cortex was inferior in this regard

Key words bone formation, osteogenesis, periosteum, osteoperiosteum, thickness of osteoperiosteal graft

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In a previous study (Poussa & Ritsilä 1979) the osteogenic capacities of free periosteum and 100 µm thick osteoperiosteum were compared. The study revealed that the bone-forming capacity of free periosteum was faster and more vigorous. The cortical bone had a suppressing effect upon proliferation of periosteal cambium cells.

The new bone both in free periosteal and osteoperiosteal grafts is produced by the cambium layer cells (Tonna & Cronkite 1963, Ritsilä et al 1972, Ritsilä & Alhopuro 1973, Poussa & Ritsilä 1979). In osteoperiosteal grafts resorption of the cortex occurs first and then proliferation of the cambium cells. It was proposed that a thinner layer of bone attached to the periosteum would be less impeding for the osteogenesis than a thick cortical layer. A study was therefore made to compare the bone-forming capacities of free periosteum, 100 µm thick osteoperiosteum and osteoperiosteum with full thickness cortex.

MATERIAL AND METHODS

Series I

In this series the osteogenic capacity of free periosteum was compared with that of 100 µm

Lorenzi 1970). Both grafts were taken from the proximal third of the medial facet of the tibia. The periosteal graft was taken by stripping, the osteoperiosteal graft was detached as a whole with a circular saw. The cortex was made thinner by reaming the excess bone from the medullary side of the graft. The 100 micron thickness was checked with an operating microscope. Some osteoperiosteal grafts were detached with a sharp knife. Thereafter these two graft types were fixed to two adjacent lumbar vertebra between the spinous and mamillary processes. There were thus 82 histologically studied periosteal and osteoperiosteal grafts and 24 periosteal and osteoperiosteal grafts studied with triple fluorochrome labelling.

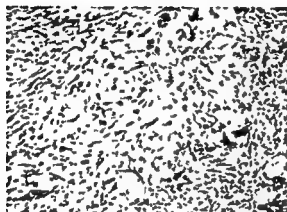


Figure 1. Low power photomicrograph of the lumbar vertebra 3 days postoperatively ($\times 4$). There is marked proliferation in the periosteum (arrow). This is better seen in the higher magnification ($\times 25$) on the left, where osteoid-like material can be seen between the proliferating cells. The 100 microns osteoperiosteum looks inactive, also in the higher magnification on the right ($\times 100$) (van Gieson). (Fb=fibrotic layer, CL=cambium layer, C=cortex)

Series 2

The second series comprised 25 six-week-old rabbits with 50 periosteal and 50 osteoperiosteal grafts with full thickness cortex. The bone marrow was rinsed out with Ringer's solution.

The rabbits were killed 3, 4, 5, 6, 7, 8, 10, 14, 18, 21, 28, 42 and 84 days after grafting. The histological specimens were prepared according to the same method as in a previous study (Poussa & Ritsilä 1979). In series 1 triple fluorochrome labelling was carried out in 12 rabbits according to the following scheme

Postoperative labelling

No. of animals	Tetrac 50 mg/kg	Haematoporp 300 mg/kg	DCAF 20 mk/kg
	Day	Day	Day
8	5	10	15
6	18	20	25

The rabbits were killed 2 days after the labelling. The specimens were fixed in 70 per cent alcohol for 24 hours, followed by dehydration in rising alcohol series. Methylmethacrylate was used for embedding, 150 μ m sections were cut and polished to 100 μ m thickness. The sections were studied with a fluorescence microscope with UV excitation, and photographed with a standard photomicrographic apparatus.

RESULTS

Series 1

Histology

3-4 days. After 3 days marked proliferation of the cambium layer can be seen in the grafted periosteum. Numerous small

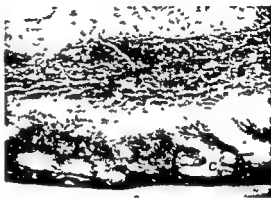
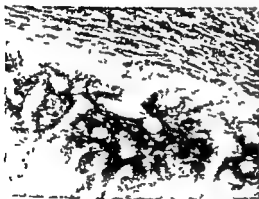
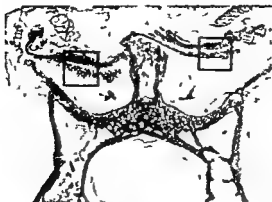


Figure 2 Low power photomicrograph of the lumbar vertebra 5 days postoperatively ($\times 4$). New bone has been formed by both the periosteum on the left and the 100 micron thick osteoperiosteum on the right. The immature structure of the newly formed bone is better seen in the higher magnifications ($\times 125$) (van Gieson).

Nb = fibrotic layer, NB = new bone, C = cortex

shaped, round and ovoid cells as well as osteoid-like material are seen among the cells (Figure 1).

In the 100 μ m osteoperiosteum no such cell proliferation is observed. The cambium layer between the fibrous layer and the cortex remains inactive (Figure 1).

After 4 days the first signs of cartilage and bone formation are seen in both grafts.

8 days The free stripped periosteum has formed bone. The formed bone is structurally immature and coarse-fibred. In some sections no cartilage can be seen (i.e. 5 days postoperatively) (Figure 2).

In the 100 μ m osteoperiosteum there is no formation of new bone. This woven bone is seen between the periosteum and the

cortex. Structurally the new bone is similar to that formed by the free periosteum (Figure 2). Loose connective tissue is seen between the fibrous layer of the periosteum and the new bone. Qualitatively the microscopic picture of the osteogenic process appears identical in both graft types.

10–18 days The grafted periosteum has in all sections formed a cartilage-bone bridge between the spinous and mamillary processes (Figure 3). Typical secondary cartilage cells are seen between the bone and the cartilage.

The 100 μ m periosteum has reached the same stage of osteogenesis. Bone and cartilage are consistently seen between the periosteum and the cortex (Figure 3).

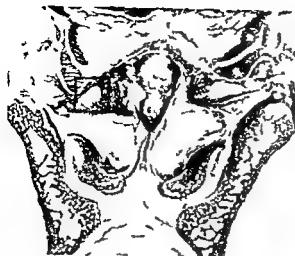


Fig. 2. Bony bridge.

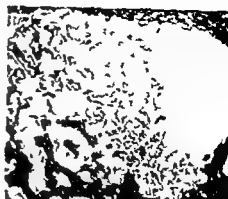


Fig. 3. Postoperatively Cartilage
magnification ($\times 125$)

21 days There is a uniform bony bridge between the fixation points of the grafts. The new bone formed is still structurally immature and osteoblasts line its trabeculae. There is no difference between the developmental stage in the two graft types.

Later on (28–84 days postoperatively) the bone structure matured and resembled that of the neighbouring vertebral processes.

Triple fluorochrome labelling

three dyes were seen in all of the sections. the periosteal grafts labelled between 5–15 days tetracycline (yellow dye) was seen facing the underlying muscle haematoporphyrin (red dye) in the middle and DCAF (green dye) in the upper part of the grafted periosteum. This revealed that periosteum formed bone in its cambium layer 5–15 days after grafting. In the 100 μ m osteoperiosteum the dyes appeared in the same order between the cortex and the periosteum (Figure 4).

In the grafts labelled 15–25 days postoperatively the dyes showed up with equal intensity both in the periosteal and osteoperiosteal grafts. The three dyes were distinguishable but there were not such clear-cut colour lines as in the grafts labelled at earlier stages of ossification.

Series 2

Histology

1–10 days Free periosteal grafts of cartilage and bone as described in Series 1.

The most remarkable feature of the osteoperiosteum with full thickness cortical bone necrosis and dissolving of the cortical bone. The nucleoles in the lacunae appeared rounded even though the bony structure was disintegrating. In some areas there was invasion towards the cortical bone from the periphery. There was no cell proliferation in the periosteum covering the cortex.

11–21 days The cortical bone was disarranged. There was cell invasion into the cortex both from the muscular tissue between the graft and from the periosteum above the cortex. The cell population consisted of spindle-shaped, ovoid and round cells. In some osteoclasts were seen (Figure 5). There was only weak new bone formation and resorption cavities.

28–84 days Resorption of the graft and formation of new bone on both sides had progressed so that symmetrical bone bridges had grown between the spinous and transverse



Figure 4 Transverse section of the lumbar vertebra with periosteal (on the left) and 100 μ m osteoperiosteal (on the right) grafts labelled with the triple fluorochrome method. Labelling was started 5 days postoperatively with tetracycline, followed at 5 day intervals with haematoporphyrine and DCAF, and the rabbit was killed 2 days later. The dyes are seen separately as colour bands. The development of new bone appears symmetrical in both grafts ($\times 5$).

processes. Also the bone structure matured in the same manner as in Series 1.

DISCUSSION

Conventional histological techniques formed the basis of this investigation and triple fluorochrome labelling was used as a complementary method. Histological methods seem to be suitable for the study of osteogenesis in periosteal grafts, the separate phases of bone formation can be easily recognized. It is not, however, possible to study the exact cell kinetics with routine histological methods. This has been performed by using tritiated thymidine (Tonna & Cronkite 1963). However, since Gulch et al. (1958) demonstrated the binding of tetracycline to regions of new bone formation this method as well as the various combinations of different fluorochrome dyes has gained increasing popularity in the study of osteogenic processes.

When bone was formed, cartilage was usually seen first, later to be replaced by new bone. In some sections in the histological study bone was observed 5 days

postoperatively in the periosteal and 100 μ m thick osteoperiosteal grafts, but there was no trace of cartilage. Two days earlier in the periosteal grafts osteoid-like material was seen among the proliferating cells of the cambium layer. In series 1 sections 7–14 days postoperatively cartilage was always present, proportionally decreasing with time. We do not know the exact mechanism or cause of cartilage formation in osteogenesis, but here the cartilage formation was always temporary and was replaced by bone. According to Ham (1930) osteogenetic cells have dual potentiality, being able to form bone or cartilage in response to the degree of vascularization in the area in which they differentiate. In Basset's studies (1962) bone was formed in the culture media when a high oxygen pressure was used, and cartilage and tendon like tissue in lower oxygen concentrations. Also the effect of stretching or compressing the culture can be explained by the differences in oxygen pressure.

During the first days tissue fluids aid the nutrition of the grafts but as the cell proliferation progresses the development of circulation should progress with the same speed or anoxia occurs with consequent

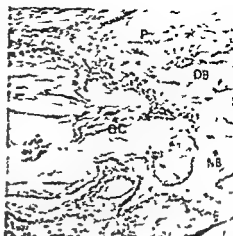


Figure 5 Low power photomicrograph of the lumbar vertebra 21 days postoperatively. Free periosteal graft on the left has formed a bone bridge. On the right osteoperiosteum with full thickness cortex is forming ($\times 5$). On the right in the higher magnification ($\times 125$) there is cell intonation from the surrounding tissues, from the periosteum above and the muscle beneath. Some osteoclasts (OC) formation of new bone (NB) (H-E stain) (P=periosteum, OB=old bone)

cartilage formation. Under ideal environmental conditions during the first 5 days bone can probably be formed directly through the activity of the cambium layer cells. During the period 7 to 14 days postoperatively cartilage formation was consistently seen, during this period cell proliferation is probably so profuse that relative anoxia frequently occurs resulting in cartilage formation.

In an earlier paper (Poussa & Ritsilä 1979) a hypothesis was presented that a thinner cortical bone layer attached to the periosteum could in theory result in better osteogenesis than the 200 micron thick osteoperiosteum. The results of the present study seem to confirm this theory. Free periosteum was osteogenically similar to 100 micron thick osteoperiosteum. The only difference was the more vigorous proliferation of the cambium layer cells during the first 3 postoperative days. The easier development of circulation in the periosteal graft may be the main reason for the differences between these two grafts.

Some previous experimental studies (Triner 1912, Davis & Hunnicutt 1915, Melcher & Accursi 1971) have dealt with osteoperiosteal grafts. New bone formation was uniformly observed. Unfortunately the authors do not

give exact details about the thickness of cortical part of the graft. Keith (1934), Siffert (1955) studied osteogenesis with bare cortical shavings without periosteum. Keith used cortical shavings from the radius. New bone formation was observed in young animals provided that there were not too many fractures in the graft. In Siffert's studies adult rabbits were used and the graft material consisted of tibial shavings. As a result the shavings were mainly destroyed by a very strong phagocytosis. The difference between the above-mentioned studies and the present one is that here the cortical shavings with periosteum were used and new bone formation was consistently achieved.

There are many earlier studies concerning the reorganization of osteoperiosteum with full thickness cortex (Axhausen 1911, Vainio 1957, Puranen 1967). Comparison with the present study is difficult because of the different experimental circumstances. In the present study the time lag between transplantation and new bone formation was 3 weeks in the case of osteoperiosteum with full thickness cortex. In Vainio's study a callus was seen 2 weeks after transplantation.

his rabbits were full-grown and ours 6-week-old. In our experiment the grafts were ad between the tops of the spinous and spinous processes and Vainio's grafts were deep in the muscle tissue near the intervertebral joint where the nutrition is better.

From the present study we conclude that also a thin cortical component of an osteoperiosteal graft has, during the first 3 days, an inhibiting effect on the proliferation of the cambium layer cells. Because circulation is mandatory for osteogenesis (Trueta 1963) the delay in the formation of circulation may explain the slight differences between the periosteum and the 100 micron thick osteoperiosteum. These circulatory studies will be reported later.

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CHRONIC RECURRENT MULTIFOCAL OSTEOMYELITIS

A New Clinical-Radiological Syndrome

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Chronic recurrent multifocal osteomyelitis is characterized clinically and radiologically by multiple, sometimes symmetrical, infectious bone lesions and a prolonged course over several years with relapses and new lesions. The distribution of the osteolytic bone lesions follows the pattern of acute haematogenous osteomyelitis in infancy and childhood. The aetiology and pathogenesis of this disease is unclear. A 5-year-old girl with this disease and 19 similar cases from the literature are reviewed.

Key words: osteomyelitis, multifocal lesions, chronic recurrent disease

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Medion et al. (1972) reported four children with a subacute or chronic symmetrical osteomyelitis. Since then 13 other cases have been reported by Gustavson & Wilbrand (1974), Probst (1976) and Probst et al. (1978) and the term chronic recurrent multifocal osteomyelitis (CRMO) has been suggested for his condition. Another two cases with a similar condition have been reported by Reipert & Campbell (1970) and Willert & Anderle (1977). A further report of a girl with CRMO is presented in this article.

swelling in her left ankle. Her general condition was good. She was without fever. She presented swelling and tenderness of her left ankle and moderate ankle joint effusion.

On admission skeletal roentgenograms showed lesions in both distal tibial metaphyses, in the left distal tibial epiphysis, in the left talus (Figures 1, 2) and also in the left distal femoral epiphysis (Figure 3). Skeletal X-ray survey was otherwise normal. Skeletal scintigrams (100 MBq 99m Tc-Sn-diphosphonate iv) showed pathologically increased activity in the left distal tibia and the left talus, corresponding to the X-ray findings, and also in the right sacroiliac joint.

The ESR was 50 mm/hour and the white cell count 29,000/mm³. The alkaline phosphatase was 436 units/l (normal for her age), the antistreptolysin titre (AST) 250 units/ml (slightly elevated) and the antistaphylococcal titre (ASTA) 40 units/ml (normal). The Tuberculin test, Widal's test and tests for rheumatoid factor and antinuclear factor (ANF) were all negative. Serum electrophoresis was normal except for a little increase in α -2 globulin and the quantitative serum immunoglobulin assay and C-reactive protein (CRP) were normal. From an open biopsy

REPORT

The patient was a girl who limped on one leg (the left one) for a week at 4 years of age. Clinical and radiological examination at that time was normal. A year later, at the age of 5 years, she was admitted to the hospital after 3 months of increasing pain and swelling on her left leg and increasing pain and



Figure 1 Osteolytic lesion in the right distal tibial metaphysis

Figure 2 Osteolytic lesions in the left distal tibial metaphysis, in the medial part of the distal tibial epiphysis and in the distal end of the left talus

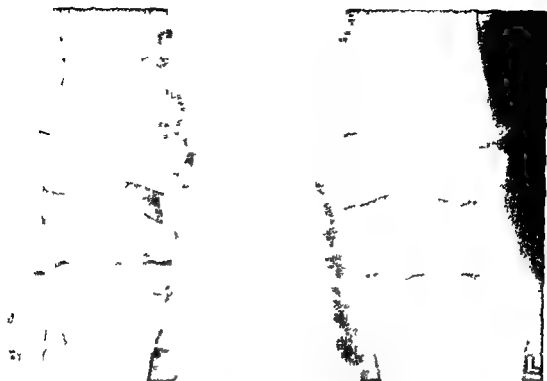


Figure 3 A defect in the lateral part of the left distal femoral epiphysis: an osteomyelitic focus or a developmental radiolucency?

of her left distal tibial metaphysis the histopathological findings showed a nonspecific inflammatory process with only slight infiltration of plasma cells, and the aerobic and anaerobic cultures from the tissue showed no growth.

A diagnosis of CRMO was made and the girl was dismissed without treatment or restrictions. Her symptoms and signs subsided during the next 3 months and the ESR and white cell count gradually became normal. In the following 10 months she has been in good health and symptom-free.

DISCUSSION

CRMO is predominately affecting children and adolescents, is characterized clinically by an onset of local swelling and pain in affected bones, usually accompanied by a low grade fever and moderately elevated ESR, and the absence of general illness. Joint involvement associated with the involvement of

articulating bones seldom occur according to Probst et al (1978). They also reported 6 out of 13 patients with concomitant palmoplantar pustulosis.

In contrast to the multifocal, sometimes symmetrical radiological findings (Table 1) the symptoms may be related to only some of the bone lesions. During its subacute or chronic course recurrent periods of exacerbations or relapses occur after varying intervals. The mean duration of the disease is 6 years (range 1–15 years) but subsequent lesions have occurred after 3 to 6 years without symptoms (Probst et al. 1978).

The sites of predilection follow the pattern of acute haematogenous osteomyelitis in infancy and childhood i.e., the metaphyses of the long and short tubular bones. The proximal and distal tibial metaphyses, the distal femoral metaphyses as well as the sternal ends of the clavicles are particularly

Table 1 The distribution of bone lesions in 20 patients with CRMO (19 cases from the literature and one case reported here)

	Right	Left
Mandible	1	1
Clavicula	7	8
Costa		1
Sacroiliac joint	1	1
Pubis	2	1
Humerus	2	
Radius	3	1
Femur	3	6
Tibia	15	15
Fibula	5	4
Metacarpal		5
Metatarsal	3	
Talus		1
Sternum	3	
Spine	12	

Number of bones affected 15 Number of bone lesions 101, mean 5 lesions per patients.

prone to be affected (Gustavson & Wilbrand 1974, Probst 1976). Our patient seems to be the first reported with lesions in the talus and probably in the epiphyses, however, in the epiphyses growth irregularities are quite common. Radiologically, there are osteolytic bone lesions with an inflammatory component and reactive changes. Immediately adjacent to metaphyseal growth plates, there are numbers of small rounded lacunar lesions while in the flat bones the sclerotic reaction tends to be more diffuse (Giedion et al 1972, Probst et al 1978). Skeletal scintigrams may be helpful in detecting new lesions.

The aetiology and pathogenesis of the disease is unclear. Cultures of bone biopsy material and blood usually show no growth (Giedion et al 1972, Probst et al 1978). Giedion et al. (1972) postulated that this disease might be an autoimmune disease of bone, but usually an extensive search for humoral and cellular immunological or haematological defects, as well as rheumatoid arthritis, is unsuccessful. The histopathological findings are usually non-

specific, indicating a chronic inflammatory process (Probst et al. 1978), but sometimes plasmacellular osteomyelitis may be encountered (Giedion et al. 1972, Willett Enderle 1977). However, CRMO can be distinguished from plasmacellular osteomyelitis which is a primary, monofocal, chronic haematogenous osteomyelitis caused by *staphylococcus aureus* (Exner 1970). Multiple symmetrical bony lesions are seen in newborn children with sickle-cell anaemia bone infarcts (Bohrer 1970) or salmonella osteomyelitis (Engh et al 1971), but the radiological picture is quite different. Round cell sarcoma with metastases, fibrous dysplasia and eosinophilic granuloma may cause radiological diagnostic problems in monofocal lesions.

In the treatment of CRMO antibiotics have no obvious effect on the course of the disease. Corticosteroids have been tried during the exacerbations (Probst et al 1978). The prognosis is good, but the course prolonged. Correct diagnosis of CRMO is important in order to avoid unnecessary diagnostic procedures and treatment. Once the diagnosis has been established the radiological follow-up should be kept to a minimum.

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EFFECTS OF OXYTETRACYCLINE ON SOLUBILITY AND SYNTHESIS OF COLLAGEN IN YOUNG RATS

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In a recent study we demonstrated that the antibiotic oxytetracycline reduces both growth and mechanical strength of bone and skin in young rats. The present study deals with the effect of 14 days of medication

^{14}C proline

medication

the femurs and skin of rats receiving oxytetracycline than in controls. No effect of the antibiotic on the rate of collagen synthesis could be demonstrated. These findings may indicate that oxytetracycline in young rats causes reduced mechanical strength of bone and skin by interfering with the cross-linking of collagen.

Key words: bones, collagen, oxytetracycline, rats, skin, solubility, synthesis, tetracyclines

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Antibiotics of the tetracycline group may impair both growth and strength of growing bones (Coblan et al 1963, Gudmundson 1971a). The nature of this impairment, however, remains unsettled (Uitto 1976). In a previous study (Engesaeter & Skar 1978) we have shown that oxytetracycline reduces the mechanical properties not only of bones, but also of skin. As collagen acts as the major supporting framework of both tissues, an effect of oxytetracycline on collagen would be a plausible explanation for these findings.

The purpose of the present study was to investigate the influence of oxytetracycline on the synthesis and on cross-linking of collagen in bone and skin. Synthesis was assayed by the conversion of ^{14}C -proline to ^{14}C -hydroxyproline (Firschein 1969). Cross-linking of collagen was assessed indirectly by the solubility of collagen in saline solution (Lapière & Nusgens 1976).

MATERIALS AND METHODS

Animals

Twenty-four male Wistar rats, initially weighing 32-37 g, were used. Half of the animals received intraperitoneal injections of 2.8 mg oxytetracycline (Terramycin[®] Intravenous, Pfizer) in 0.5 ml water every 12th hour for 14 days. In the middle of the period 49 mg/kg was given twice a day. The other half of the animals, serving as controls, received corresponding injections of the vehicle. Plasma concentrations of the antibiotic were comparable with therapeutic levels in man. Details of the rats and medication are given in a previous paper (Engesaeter & Skar 1978). The same animals were used in both studies.

Biochemical analyses were performed on skin and bones (left femur and tibia) from animals killed at the end of the medication period and 3 weeks later. Six rats were examined in each group. Twenty-four hours before the animals were put to death 15 μCi L-(U- ^{14}C)proline (The Radio-

chemical Centre, Amersham, specific activity 285 mCi/mmol) per 100 g body weight was injected intraperitoneally. Blood samples were obtained by heart puncture. All materials were stored at -20°C until examined.

Bone analyses were performed on the left femur and the proximal part of the left tibia. Before the femur was analysed, cartilages and epiphyses were removed. The major part of the longitudinal growth of the tibia takes place in the epiphyseal disc near the knee (Tapp 1966). As bone produced during the medication period was of special interest and as the tibia grew about 8 mm during the medication period, the 8 most proximal millimetres were studied in the animals killed at the end of medication. In rats killed 3 weeks later 15 mm of the metaphysis had to be examined to be certain that bone produced during the medication period was also included. Skin analyses were performed on skin from the back of the rats, i.e. the most cranial of the three skin specimens used in the mechanical testing (Engesaeter & Skar 1978).

Collagen analyses

Soluble collagen related to total collagen was assessed by modifications of the methods described by Kivirikko et al. (1965) and Gudmundson (1971b). Bone and skin specimens were placed in acetone for 7 days with two changes of acetone, dried in air at 35°C for 3 days, weighed (dry weight). Each specimen was minced with scissors and homogenized in 1.0 M NaCl with an Ultra-Turrax[®] (18K, & Kunkel, Staufen, West Germany). The homogenization was performed for 15 seconds twice with a 30-second interval and in an icebath to prevent warming of the samples. Thereafter the homogenizer was washed in 4 ml 0.15 M NaCl for another 15 seconds. The two solutions were pooled, extracted in a shaking machine at 4°C for 20 hours and centrifuged at 14000g for 4 hours. The supernatant obtained was called "the salt soluble" fraction and the precipitate "the insoluble" fraction. Both fractions were hydrolysed at 125°C for 18 hours: the salt soluble fraction in 4 ml concentrated HCl and the insoluble in 4 ml 6M HCl.

As hydroxyproline is practically unique to collagen (LeRoy 1967) the quantitation of collagen was done by measuring the hydroxyproline in the hydrolysates using the method of Firschein (1969). The rate of collagen synthesis was assayed by the conversion of ^{14}C -proline to ^{14}C -hydroxyproline (Firschein 1969), as proline first is incorporated into the polypeptide and then

hydroxylated to yield hydroxyproline (Urnell al 1966).

The radioactivity was measured in a liquid scintillation counter (Nuclear Chicago Mark with Dilusolve[®] (Packard Instr. Corp.) scintillation solution. Counting efficiency determined by the two channels ratio method, 70 per cent.

Serum albumin

Total serum protein was measured by a turbidimetric method and the albumin fraction of the protein by photometric scanning of a cellulose acetate gel electrophoresis. Albumin synthesis assessed by measuring in the liquid scintillation counter the radioactivity in the albumin fraction of another cellulose acetate gel electrophoresis.

Serum iron

Serum iron was assayed by means of a colorimetric method (Bjerve 1976) using a spectrophotometerically the coloured ferrous complex (Bjerve 1976).

Serum copper

Ninety-nine per cent of rat serum copper associated with ceruloplasmin and serum albumin.

Statistics

The median with 25- and 75-percentiles was used as an expression of the average and the dispersion of the measured values. Statistical significance evaluated by the Wilcoxon test for two samples (one-tailed test) and differences were considered significant if $P \leq 0.05$ (Diem & Lentner 1975).

RESULTS

At the end of the medication period the soluble fraction of collagen was significantly higher in both skin and femur of the tetracycline treated rats compared to controls (Figure 1). In the tibia metaphysis the same trend was found, the soluble fraction constituted 1.67 per cent of collagen in the rats receiving oxytetracycline and 1.47 per cent in the controls but this difference did not reach statistical significance.

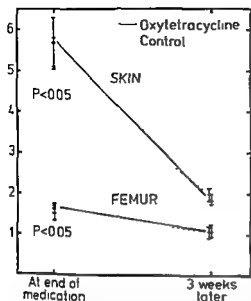


Figure 1 Collagen soluble in 0.15M NaCl solution in percent of total collagen in femur and skin of the oxytetracycline treated rats and of controls. Six animals in each group (median with 25- and 75-fractiles)

0.07) Three weeks later no significant differences were observed in the solubility of collagen between animals treated with oxytetracycline and controls, neither in bones nor in skin.

The activity of ^{14}C -hydroxyproline in tibia and femur is given in Table 1. No differences in the rate of collagen synthesis were observed at any time. Table 2 shows the content of collagen related to dry

weight of the specimens expressed as per cent hydroxyproline to dry weight. No differences were found between the two groups during the observation period.

Radioactivity of albumin and concentrations of ceruloplasmin and iron in serum are given in Table 3. No differences between the two groups could be detected from these parameters.

DISCUSSION

This study in young rats reveals that 14 days of oxytetracycline medication causes increased solubility of collagen in skin and bone. No effect of the antibiotic on the rate of collagen synthesis could be detected.

Collagen molecules are normally linked together in fibres by specific covalent bonds known as cross-links. If this cross-linking is disturbed in any way these fibres do not attain the necessary tensile strength (Uitto & Lichtenstein 1976). Defective binding of the collagen molecules within fibres causes not only reduced mechanical properties, but also increased solubility of collagen (Lapière & Nusgens 1976). The term "soluble collagen" is, however, biologically heterogeneous, depending on the nature of the extractants and on the conditions (temperature, ionic strength, pH) of the procedure. The more efficient the method of extraction the greater

Table 1 Specific activity of ^{14}C -hydroxyproline in tibia and femur of rats treated with oxytetracycline and controls. Six animals in each group (median with 25- and 75-fractiles)

	FEMUR		TIBIA		SKIN	
	Spec. activity of hyp (dpm/nmol hyp)		Spec. activity of hyp (dpm/nmol hyp)		Spec. activity of hyp (dpm/nmol hyp)	
	At end of medication	3 weeks later	At end of medication	3 weeks later	At end of medication	3 weeks later
OXYTETRACYCLINE	1.68 (1.46-1.73)	1.19 (1.19-1.20)	2.18 (2.03-2.27)	1.66 (1.65-1.74)	1.09 (0.90-1.22)	0.48 (0.40-0.56)
CONTROL	NS 1.68 (1.61-1.78)	NS 1.26 (1.16-1.32)	NS 2.23 (1.99-2.49)	NS 1.91 (1.78-2.17)	NS 0.96 (0.88-0.97)	NS 0.53 (0.44-0.55)

Table 2 Amount of hydroxyproline (collagen) in percent of the dry weight of femur proximal to metaphysis and skin of the oxytetracycline treated rats and of the controls. Six animals in each group. NS=Not significant (Median with 25- and 75-fractiles)

	FEMUR (Hyp in % of dry weight)		TIBIA (Hyp in % of dry weight)		SKIN (Hyp in % of dry weight)	
	At end of medication	3 weeks later	At end of medication	3 weeks later	At end of medication	3 weeks later
OXYTETRA- CYCLINE	1.83 (1.79-1.87)	1.87 (1.81-1.93)	1.92 (1.78-2.00)	1.81 (1.76-1.87)	4.35 (4.11-4.58)	7.10 (6.70-7.2)
	NS	NS	NS	NS	NS	NS
CONTROL	1.82 (1.76-1.93)	1.83 (1.74-1.95)	1.80 (1.69-1.91)	1.75 (1.69-1.86)	4.50 (4.24-4.82)	6.57 (6.48-6.7)

the heterogeneity (Jackson & Bentley 1960). Cold neutral saline solutions, as used in our study, are thought to act by disrupting non-covalent interactions and in this way can solubilize noncovalent cross-linked collagen (Bornstein & Traub 1979). In our study increased solubility of collagen was observed in the same bone and skin specimens that previously had been shown to have reduced mechanical strength (Engesaeter & Skar 1978) which may indicate that oxytetracycline interferes with the covalent binding of collagen in the fibres. These results compare favourably with those achieved by (1971b). He found reduced strength and increased salt solubility of collagen in fracture callus of oxytetracycline-treated mice.

Oxytetracycline could be considered to

influence the cross linking of collagen several ways. Firstly, oxytetracycline may have a mode of action similar to that of lathyrogens. These drugs cause reduction of mechanical strength and increased solubility of collagen by inhibiting the formation of cross-links (Barrow *et al.* 1974). This is achieved by inactivating the enzyme lysyl oxidase which catalyses the first step in cross-linking of collagen (Siegel 1976). Lysyl oxidase requires copper (Siegel *et al.* 1970) and as tetracyclines have chelator properties (Ibsen & Urst 1964) oxytetracycline may inhibit the enzyme by binding copper (Lancet 1978). In our study, however, reduction in serum copper was detected. On the other hand this does not exclude possibility of local reduction in the tissues.

Secondly, the observed effects of

Table 3 Radioactivity of albumin (dpm/g albumin) and concentrations of ceruloplasmin and iron in serum of the oxytetracycline treated rats and of the controls. Five animals in each group. NS=Not significant (Median with 25- and 75-fractiles)

	ALBUMIN Radioactivity of albumin (dpm/ μ g albumin)		CERULOPLASMIN (IU/ml)		IRON (mol/l)
	At end of medication	3 weeks later	At end of medication	3 weeks later	At end of medication
OXYTETRA- CYCLINE	2.79 (2.68-3.01)	2.85 (2.43-3.03)	0.23 (0.18-0.26)	0.21 (0.19-0.24)	62.0 (50.0-73)
	NS	NS	NS	NS	NS
CONTROL	2.26 (1.77-2.57)	2.95 (2.65-3.20)	0.25 (0.19-0.27)	0.23 (0.21-0.24)	77.4 (57.8-84)

acycline could be explained by a defect in conversion of pro collagen to collagen, as dermatosparaxis, a heritable disease in cattle and sheep (Uitto & Lichtenstein 1976) anticipated that in this condition a Ca^{++} dependent enzyme, amino-terminal pro-collagen protease, has reduced activity. The absence of amino-terminal extension on collagen results in deficient formation of the molecular cross-links. This biochemical defect explains the extremely fragile skin and increased extractibility of collagen which are found in this condition.

The observed increased fraction of soluble collagen in the oxytetracycline treated animals could also be considered to be caused by an increased degradation of collagen. If increased degradation gives increased content of collagen cleavage products in the tissues, these would have been measured as soluble collagen. The observed reduced mechanical strength could then simply be a consequence of a reduced amount of collagen. Collagenase-induced collagen fragments would, however, not be expected to accumulate in the tissues, as they have lost the protection afforded by the triple helical conformation of the native molecule and thereby have become susceptible to a variety of extracellular proteases (Bornstein & Traub 1979). In addition, it may be difficult to understand why oxytetracycline should increase degradation of collagen in both bone and skin if the produced collagen were completely normal.

The solubility of dermal collagen declined both in oxytetracycline treated and control animals during the 3 weeks following the medication period. Since the rate of collagen synthesis is known to affect the solubility (Gross 1958) this may be explained by the reduced rate of collagen synthesis observed in both groups at that moment (Table 1). Similar age-related changes in the solubility of skin collagen in rats have been described by Dawson & Milne (1978).

Tetracyclines exert their antibacterial effect through inhibition of the protein synthesis. Such an inhibition has also been demonstrated in mammalian cells (Yeh &

Shils 1966, Morgan & Ribush 1972, Vazquez 1974). In our study, however, no diminution of the synthesis of albumin or collagen was detected.

Based on *in vitro* experiments several authors (Halme et al 1969, Uitto 1975) have proposed that tetracycline selectively inhibits collagen synthesis by binding ferrous iron which is required in the hydroxylation of proline by prolyl hydroxylase (Bornstein & Traub 1979). In our study, however, no significant reduction was found, at the end of the medication period, in iron concentration in serum of the oxytetracycline treated rats compared with the controls. Furthermore the amount of collagen in relation to dry weight of the bone and skin specimens was unaffected by the medication. These findings are in accordance with the statement of Chvapil et al (1974) that the hydroxylation of proline could not be inhibited by administration of chelating agents to intact animals.

In conclusion we have shown that oxytetracycline in young rats reversibly reduces the mechanical properties and reversibly increases the salt solubility of collagen in bone and skin. Oxytetracycline may cause these effects by interfering with the cross-linking of collagen.

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ANTIBIOTICS AND BONE CEMENTS

Experimental and Clinical Long-Term Observations

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Comparing several antibiotics and different bone cements, the mixture of

was observed for more than 5 years. Gentamicin proved to be stable in Palacos R for the whole period of time

The release of 12 antibiotics from Palacos R was evaluated *in vitro*. Four other bone cements were included in this study as well in order to evaluate the leaching of gentamicin from these materials. The combination Gentamicin Palacos R (GP) showed a 2-3 fold higher and much more prolonged release than did the other mixtures. From this investigation which also included studies of commercially available antibiotic bone cement mixtures, it is quite obvious that there exist distinct differences in the various bone cements as well as in the various antibiotics as regards their qualification for use in alloarthroplasty.

Pharmacokinetic studies in patients after implantation of GP showed low gentamicin concentrations in serum (on average 18 µg/ml) and urine. However in wound exudate derived directly from the vicinity of the implanted cement gentamicin concentrations up to 150 µg/ml were observed. Also in tissue samples from the vicinity of the implant high concentrations were measurable for a long period of time (up to 5½ years).

Key words: antibiotics, bone cements, gentamicin, Palacos R, pharmacokinetics, tissue concentrations.

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Gentamicin loaded polymethylmethacrylate (Palacos® R) has been successfully used for about 10 years in Europe (Buchholz & Engelbrecht 1970). In alloarthroplasty, mainly the insertion of total hip endoprostheses, the use of this antibiotic bone cement mixture has diminished the rate of postoperative infection markedly (Buchholz & Gartmann

1972, Wannse & Rogge 1976). Furthermore it has been possible for the first time to treat the infection locally, using Gentamicin-Palacos R (GP) while changing the infected endoprosthesis (Buchholz 1973, Carlsson et al 1978).

From extensive experimental and pharmacokinetic studies during this period of time it has been observed that there exists a distinct and very prolonged leaching of antibiotics from bone cements which leads, also *in vivo* to high local antibacterial con-

Refobacin® Palacos® R manufactured by E Merck Darmstadt, in collaboration with Kulzer & Co., Ltd. Bad Homburg v d H. Federal Republic of Germany

centrations after GP implantation (Wahlig et al 1972b, Wahlig & Buchholz 1972). This paper deals with the release kinetics of several antibiotics from different bone cements and long-term observations with GP, *in vitro*, in animals and in patients.

MATERIALS AND METHODS

Microbiological determination of antibiotics The concentrations in phosphate buffer, serum, urine,

lividomycin, neomycin, erythromycin, dicloxacillin, cefazedone), *Micrococcus flavus* ATCC 10240 (bacitracin), *Bordetella bronchiseptica* ATCC 4617 (colistin), *Bacillus cereus* ATCC 11778 (tetracyclin), *Sarcina lutea* ATCC 9341 (fucidinic acid, lincomycin, clindamycin). Standard dilutions were always prepared in appropriate media.

In vitro studies To determine the release of antibiotics from the hardened bone cements, standardized cylinders were made from commercially available GP and two other antibiotic bone cement mixtures. Furthermore, cylinders were prepared from Palacos R and four other cements used in THR after having mixed 12 different antibiotics into the polymer powder. The cylinders were 25 mm in diameter and 10 mm high. The weight was 5.9 g (on average), the volume 4.8 cm³ and the surface area 17.7 cm². In the long term *in vitro* studies with GP, two other cylinder sizes were used as well: diameter again 25 mm but height 20 and 3 mm, weight 11.5 and 2.1 g, volume 9.8 and 1.5 cm³, surface area 25.5 and 12.1 cm². The antibiotic concentrations used are indicated in Tables 1-7. The right column in Tables 1-3 indicates the total amount of antibiotics (in mg or units) released during the whole observation time (10 days).

Each cylinder was placed in a large test tube, covered by 20 ml of phosphate buffer, pH 7.4 or pooled human serum and stored at 37°C. The antibiotic concentration in the elution fluid was determined at first daily, then weekly and finally monthly, the buffer solution or serum being removed and frozen at -20°C until assayed. The

After cutting, the different fragments were dissolved separately in chloroform. Gentamicin was then extracted from the chloroform-mixture with phosphate buffer, pH 7.4 and bioassayed.

The bone cements used were Palacos R Surgical Simplex², CMW Bone Cement², Sulf 6 and Bonemite². The following antibiotics were used: gentamicin, lividomycin, neomycin, bacitracin, colistin, tetracyclin, fucidinic acid, erythromycin, lincomycin, clindamycin, dicloxacillin, cefazedone. Furthermore three commercially available antibiotic bone cement mixtures were included in this study.

In vivo studies In 14 beagle dogs the middle femur cavity was opened and after removing 2 ml marrow the cavity was filled with GP.

Tissue samples (hematoma after 3, 7, 10 and 14 days, connective tissue, cancellous bone and cortical bone) were taken from the vicinity of the GP implant after various time intervals between 1 day and 12 weeks, as well as more than 12 months, after operation. The tissues were homogenized in phosphate buffer, pH 7.4 and after centrifugation the supernatant was stored at -20°C until assay. Bone filings were prepared from the cortical bone samples and eluted in buffer.

Clinical studies After total hip replacement operations using GP in 15 patients, the gentamicin concentrations in serum and urine were in the secretion from the wound were assayed.

Blood samples were taken 30 min, 3, 8, 24 hours and 4 days after implantation of GP. After coagulation and centrifugation the serum was stored at -20°C until assay.

All urine was collected for 24-hour periods during the first three postoperative days and subsequently on days 10 and 21 after operation.

The wound secretion from a Redon drain was collected for 24-hour periods after operation including the first postoperative day.

In 18 patients it was possible to take tissue samples from the vicinity of the implant between 4 days and several months, as well as up to 12 years, after total hip replacement using GP. The preparation of the samples for bioassay was the same as described above (see *in vitro* studies).

RESULTS

In vitro studies Gentamicin, in the same way as the other antibiotics, is released from the hardened bone cements into buffer solution by diffusion, the rate of which can be readily

In order to estimate the amount of gentamicin in the test blocks after an elution period of 5 years the cylinders were cut into thin slices (~mm)

1 In vitro release of gentamicin, cefazedone and colistin from commercially available bone cements

Cement	Antibiotic 0.5 g per 34 or 40 g polymer powder	Release µg/ml at day										Day	
		1	2	3	4	5	6	7	8	9	10	I	II
(R) R	gentamicin ¹	110.0	16.4	5.4	2.4	2.2	1.7	1.1	1.5	1.1	1.3	2.86	
1		42.0	3.2	1.9	0.7	0.6	0.6	0.3	0.3	0.3	0.2	1.00	
2		56.0	3.0	0.6	0.3	0.1	0.1	0.1	0.1	0.05	0.1	1.21	
3		44.0	3.7	1.0	0.5	0.3	0.3	0.1	0.2	0.1	0.07	1.01	
4		52.0	1.6	0.7	0.5	0.4	0.3	0.2	0.2	0.2	0.1	1.14	
(R) R	cefazedone ¹	93.5	10.3	4.8	3.3	1.9	1.6	1.2	1.1	trace ²	trace ²	2.35	
1		42.0	3.4	1.5	trace ²	0	0	0	0	0	0	0.94	
2		47.2	2.7	1.3	trace ²	0	0	0	0	0	0	1.02	
3		36.9	2.3	1.1	trace ²	0	0	0	0	0	0	0.81	
(S) R	colistin- methanesulfonate	22.2	5.2	0	0	0	0	0	0	0	0	0.55	
3		7.2	0	0	0	0	0	0	0	0	0	0.14	

¹ Free substance² $<1.0 \mu\text{g/ml}$

ured *in vitro*. There was no difference in elution into phosphate buffer or pooled serum. As far as different commercially available bone cements are concerned, this study showed that the largest amounts of antibiotic were released from palacos R. Each of the antibiotics used, gentamicin, cefazedone as well as colistin, was released to a lesser extent from the other bone cements (Table 1). This was quite obvious in the case of neomycin. Whereas this

was released to a significant extent, followed by tetracycline and neomycin. The diffusion of erythromycin, bacitracin, colistin, fucidinic acid and dicloxacillin was comparatively poor (Table 2).

In a further study the release of the antibiotics from three different commercially available antibiotic bone cement mixtures was assayed. These mixtures contained gentamicin (Refobacin®-Palacos® R), neomycin/bacitracin (bone cement A) and colistin/erythromycin (bone cement B).

The results of this investigation again demonstrated that only in the case of GP were high antibiotic concentrations attainable. The amount of antibiotic released from the other bone cement mixtures was distinctly inferior (Table 3).

In a long-term study the leaching of gentamicin from palacos R was observed for a period of 5 years. A continuous release of gentamicin could be demonstrated throughout the whole period (Table 4). The largest amounts of antibiotic, however, were measurable during the first months of diffusion. Depending on the size of the test

if it was incorporated in another bone cement (Table 3). In this respect it has to be taken into consideration that the content of gentamicin in bone cement A was much higher than in the mixture shown in Table 2 (0.6 g versus 0.5 g per package polymer powder).

Comparing the release of 12 different antibiotics from palacos R, gentamicin and neomycin showed the highest and a very prolonged leaching. Beside these antibiotics cefazedone, lincomycin and clindamycin

Table 2 In vitro release of 12 different antibiotics from Palacor² R

Antibiotic	Amount ¹ per 34 g polymer powder	Release µg/ml at day										µg/l 12 h
		1	2	3	4	5	6	7	8	9	10	
Gentamicin	0.5 g	110.0	16.4	5.4	2.4	2.2	1.7	1.1	1.5	1.1	1.3	2.6
Lividomycin	0.5 g	85.9	13.4	5.5	4.9	2.9	3.3	3.0	2.1	1.9	1.8	1.6
Neomycin	0.5 g	48.9	4.7	2.8	2.0	1.7	1.5	1.3	1.1	1.2	0.9	1.0
Bacitracin	55 000 I.U.	3.7	0.4	0.2	0	0	0	0	0	0	0	1.1
Colistin	0.5 g	46.9	2.3	1.0	0.5	trace ²	trace	trace	0	0	0	1.0
Tetracycline	0.5 g	27.2	8.4	6.2	5.3	4.0	4.0	3.3	3.3	2.9	2.7	1.6
Fusidic acid	1.0 g	1.1	0	0	0	0	0	0	0	0	0	0.0
Erythromycin	0.5 g	18.0	1.9	1.0	0.6	0.6	0.4	0.3	0.3	0.2	0.3	0.9
Lincomycin	0.5 g	68.6	10.5	6.4	5.0	4.9	3.8	2.5	2.3	2.7	2.9	2.6
Clindamycin	0.5 g	43.4	11.6	9.1	7.9	5.2	6.6	5.1	4.4	4.5	4.2	2.6
Dicloxacillin	0.5 g	36.0	6.2	5.1	trace ³	trace	trace	trace	0	0	0	0.6
Cefazidone	0.5 g	93.5	10.3	4.8	3.3	1.9	1.6	1.2	1.1	trace ⁴	trace	2.6

¹ active substance² trace = <0.5 µg/ml³ trace = <2.0 µg/ml⁴ trace = <1.0 µg/ml

cylinders, between 3 and 8 per cent of the total gentamicin content was released.

By cutting the cylinders and analyzing the different fragments separately a continuous

increase in gentamicin concentration from the outer parts to the center was demonstrated.

In the center of the large blocks the full concentration of gentamicin was still detectable.

Table 3 In vitro release of different antibiotics from commercially available antibiotic bone cement mixtures

Preparation	Release µg/ml at day										µg/l 12 h
	1	2	3	4	5	6	7	8	9	10	
<u>Refobac n Palacor^(R) R</u>											
Gentamicin 0.5 g ¹ per 34 g polymer powder	110.0	16.4	5.4	2.4	2.2	1.7	1.1	1.5	1.1	1.3	2.6
<u>Bone cement A</u>											
Neomycin 0.5 g ¹ + Bacitracin 55 000 I.U. per 43.7 g polymer powder	61.7 3.3	6.0 0.2	3.1 0	2.5 0	1.5 0	0.7 0	0.7 0	0.7 0	0.9 0	0.6 0	1.5 0.7
<u>Bone cement B</u>											
Colistin 0.24 g ¹ + Erythromycin 0.5 g ¹ per 36 g polymer powder	<5.0 10.7	0 1.2	0 0.6	0 0.4	0 0.1	0 0	0 0	0 0	0 0	0 0	0.5

¹ active substance

Table 4 In vitro release of gentamicin from Palacos[®] R (mg)

Time after operation	Gentamicin release from 10 g Palacos cylinders		
	0-25 mm	0-25 mm	0-25 mm
1 day	1.20	1.10	1.30
3 days	3.00	2.20	1.40
7 days	0.150	0.062	0.034
10 days	0.125	0.058	0.010
2 weeks	0.090	0.049	0.005
4 weeks	0.054	0.029	0.009
12 weeks	3.507	2.462	1.482

in vivo studies Gentamicin concentrations in nine tissue samples taken at different times after operation are summarized in Table 5. Initially the highest concentrations were measured in the hematoma. However, concentrations were also achieved in the soft tissue and in the cancellous bone to the implant, particularly during the first and up to 4-8 weeks after operation. Even in cortical bone, up to 2 weeks post operation considerable amounts of gentamicin were found.

pharmacokinetic studies in 33 patients In 15 patients undergoing total hip replacement with GP (10 g gentamicin base per 1 pack-polymer powder) high concentrations

were found in the wound secretion (on average 41-118 µg/ml) (Table 6).

However, only small amounts of gentamicin were found in the serum. The concentration never exceeded 3 µg/ml, and was well below 1 µg/ml 6 to 8 hours after operation. This lasted for only about 2 weeks after surgery.

In the urine, gentamicin could still be measured several months after total hip replacement, but the concentrations again were comparatively low, even in the first days after the operation.

The gentamicin concentrations assayed from tissue samples which were taken from 18 patients between 4 days and 69 months after total hip replacement using GP are summarized in Table 7. Particularly in the connective tissues derived from the immediate vicinity of the implanted GP remarkably high gentamicin concentrations were observed throughout the whole period.

DISCUSSION

Antibiotics admixed with bone cements leach out of the hardened plastic material by diffusion. The amount, measurable *in vitro*, has been found to be proportional to the surface area of the cement (Wahlig et al.

Table 5 Gentamicin concentrations in canine tissues (µg/g wet weight) after implantation of gentamicin-Palacos[®] R

Time after operation	Gentamicin per 34 g polymer powder	Hematoma	Connective tissue	Spongiosa	Corticalis
3 days	1.0	7.7		4.9	4.0
7 days	1.0	10.6		5.6	5.8
10 days	1.0			6.8	3.8
2 weeks	0.5	17.1		4.8	0.6
2 weeks	1.0	29.0		4.0	2.3
4 weeks	0.5		3.7	2.8	0.8
4 weeks	1.0		4.5	2.8	0.9
8 weeks	0.5		3.0	0.3	
8 weeks	1.0		2.0	7.7	1.0
10 weeks	1.0		1.7	0.5	0.8
12 weeks	0.5		2.0	1.0	0.4
12 weeks	1.0		4.9	2.9	1.2
22 months	1.0		3.7	2.8	0.6
22 months	1.0		2.8	1.6	0.6

Table 6 Gentamicin concentrations in wound secretion, serum and urine of 15 patients after replacement using gentamicin-Palacos[®]R

Sample		Time after the operation				1st post oper day	2nd post oper day	4th post oper day	10th post oper day	14th post oper day
		0.5 h	3 h	8 h	24 h					
Wound secretion ($\mu\text{g/ml}$)	Mean				118.1	40.8				
	95% CL				79.7	15.7				
					156.5	65.9				
Serum ($\mu\text{g/ml}$)	Mean	1.82	1.34	0.72	0.13					trace ^{a)}
	95% CL	1.55	1.06	0.48	0.07					
		2.88	1.62	0.95	0.19					
Urine (recovery mg/24 h)	Mean				31.72	15.95	5.65		3.13	
	95% CL				19.4	7.4	4.4		2.3	
					44.0	24.3	6.9		4.1	
(g/ml)	range				5.1	7.1	3.0		0.7	
					76	39	16.2		7.9	

^{a)} trace = $< 0.05 \mu\text{g/ml}$

1972a) In contrast to the findings of Schurman et al (1978) a more efficient elution into serum as compared with buffer was not observed in our experiments.

As far as the kinetics of release is

concerned it is quite obvious that no bone cement or antibiotic is suitable in an antibiotic bone cement mixture for alloarthroplasty. Comparative studies that only from palacos R were high

Table 7 Gentamicin concentration in tissue samples of patients after THR using gentamicin-Palacos[®]R

Patient	Time after implantation of THR (months)	Amount of gentamicin per 34 g polymer powder	Gentamicin $\mu\text{g/g}$ tissue (wet weight)		
			connective tissue	spongiosa	cortical
V AE	4 (days)	0.5 g	14.19 (Menatoma)	14 - 23	13.11
H DE	6	0.5 g	8.26	7	0.8
N E	6	0.5 g	-	37.39	0
R A	6	0.5 g	13	6 - 22	
S M	6	0.5 g			1.4
K J	6	0.5 g		17	20.34
S A	7	0.5 g		18.18	0.3
S F	11	0.5 g	36	21	0.2
F E	11	0.5 g	18		0
R M	12	0.5 g	24	8.12	0
E E	12	2.0 g	11.21	3.11	0.9
R H	18	0.5 g	17.4	3.3	
F B	18	0.5 g	33	9	
F E	23	0.5 g	16		1.7
H G	36	0.5 g	12.17		
H G	42	1.0 g	4	0.4	0
E K	55	0.5 g	23.2		2.0
S A	55	2.0	5.4.6.6	6.6	0

concentrations and a prolonged antibiotic release attainable. Among 12 different antibiotics only gentamicin and comycin/clindamycin were found to be released in amounts, which would seem to be sufficient, if concentrations are correlated with the antibacterial activity of the compounds. In this respect gentamicin/Palacos R proved to be the most efficient and suitable combination, a result which has been confirmed by other investigators (Sattel & Bert-Bock 1973, Marks et al 1976). Because of the low concentrations used (10 g/34 g polymer powder) this was achieved without detriment to the physical strength of bone cement (Lautenschlager & Marshall 1976, Lee et al 1978), an additional factor which has to be considered in this context.

Since there have been no previous long-term observations dealing with antibiotic release from bone cements, it was interesting to find that gentamicin continued to be released from palacos *in vitro* for at least 5 years and that it remained stable during that time in the hardened material.

Long-term observations in animals and particularly in patients supported these *in vitro* findings.

In dogs, many weeks or even months after implantation of GP, high gentamicin concentrations were measured in the tissues surrounding the implant. Corresponding results in sheep have been reported by Wannke et al (1976).

Recently Schurman et al (1978) reported of therapeutic activity of GP in animal studies recording concentrations consistent with those found in this investigation.

In patients the gentamicin concentrations in serum and urine were found to be low after total hip endoprosthesis operations using GP. These findings agree well with previous results (Wahlig & Buchholz 1972). All fear of toxic side-effects is therefore groundless and it is possible to administer additional parenteral gentamicin or other antibiotics in the usual dosage should this be necessary.

In patients treated with GP there were high

concentrations of gentamicin in the wound secretion. Since the wound exudate derives directly from the area of operation, the gentamicin concentrations indicate the level present at the site of the infection.

In the case of contamination or infection, the antibiotic concentrations attainable in the tissues surrounding the implanted endoprosthesis are a good indication of the clinical efficacy of this new type of local antibiotic therapy. Due to the reduced blood supply and the penetration barriers there is no other way - even not by parenteral application of high doses - to achieve locally, directly at the site of the infection, amounts of gentamicin exceeding, for many weeks, the concentrations required to kill infecting bacteria (Reichelt et al 1976).

In tissue samples from the vicinity of the implant high concentrations were measurable for a long period of time (up to 5½ years). Again penetration or diffusion barriers may cause these comparatively high tissue levels even after such long periods of time after GP implantation.

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METAL SENSITIVITY IN PATIENTS WITH METAL-TO-PLASTIC TOTAL HIP ARTHROPLASTIES

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Out of 134 patients patch tested after total hip replacement (metal to-plastic) 13 were sensitive to one or two of the implanted metals. In a prospective series of 112 patients, nine were sensitive to nickel before and another three developed sensitivity to nickel or cobalt after the arthroplasty. In the retrospective as well as in the prospective series the complications could in all cases but one be explained on grounds other than allergy. The incidence of contact allergy to nickel before a planned arthroplasty was 12 per cent in females and 4 per cent in males. It is doubtful whether metal sensitivity could be induced by a total hip arthroplasty. However, in cases of a pre-existing metal allergy, a certain degree of caution is recommended.

Key words: arthroplasty, delayed allergy, hip, metal sensitivity

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Failure of total hip arthroplasties is most commonly the result of a deep infection or mechanical loosening. In recent years, failures attributed to metal sensitivity have been reported (Benson et al 1975, Elves et al 1975, Evans et al 1974, Munro-Ashman & Moller 1976). However, these patients were not patch tested to metals prior to the operation. The connection may therefore be questioned. According to the knowledge of the authors only two prospective investigations have been presented, both dealing with metal-to-plastic arthroplasties (Rutman et al 1977, Silvennoinen et al 1978).

The object of this investigation was to determine the incidence of delayed-type allergy to the materials used in connection with metal-to-plastic total hip replacement, and whether the implantation of prostheses made of stainless

steel or cobalt-chromium alloy might induce metal allergy and if so, whether this is of significance as regards the final outcome of the operative procedure.

PATIENTS

The material consisted of 274 patients operated upon or scheduled for operation with a metal-to-plastic total hip arthroplasty between 1968 and 1977 at the Department of Orthopaedic Surgery, Malmö General Hospital. The stem of the prostheses was made of stainless steel (Charnley) or a cobalt-chromium alloy (Vitalium) (mainly the Brunswik or Lubinus designs). The composition of the alloys is presented in Table 1.

The patients were divided into the following groups.

Group I 134 patients comprised the retrospective part of the study. The patients were patch tested 42 to 71 months after the operation. The postoperative course was uncomplicated in 99 cases. In 35 patients, one or another complication necessitated revision of the arthroplasty in 13

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Table 1 Proportions of chromium, cobalt and nickel in the prostheses

	Stainless steel (Charnley)	Vitalium (Brunswick and others)
Chromium	15-20 %	27-30 %
Cobalt	0 %	60-65 %
Nickel	10-14 %	0-4 %

cases deep infection, in 21 mechanical loosening and in one case bone resorption of obscure origin

Group II 112 patients comprised the prospective part of the investigation Patch testing was performed within 3 months before the operation, and all were retested 3 months and 1 year after the operation

Group III Another 28 patients were tested prior to a planned total hip replacement Owing to cancellation of the operation or because of too short an observation time after the operation, these patients were excluded from the prospective investigation However, these patients were included when the incidence of metal sensitivity prior to a total hip arthroplasty was calculated

The distribution of the patients in groups I, II and III according to sex and age is given in Table 2

METHODS

The patch tests were performed on the back of the patients with the standard series of allergens recommended by the International Contact Dermatitis Research Group The series of standard allergens included potassium dichromate 0.5 per cent, nickel sulphate 5 per cent and cobalt chloride 1 per cent, all dispersed in petrolatum These standard allergens were obtained from Trolab (6 B A N Hansens Alle, 2600 Hellerup, Denmark) To this battery was added methyl

methacrylate 10 per cent in stabilizers used in the cement, hydroquinone cent, benzoyl peroxide 1 per cent, and dimethyltoluidine 5 per cent all in petrolatum as well as gentamicin 10 per cent in petrolatum sometimes incorporated in the cement.

The test patches were attached to the back with Scanpor surgical (Norgeplaster A/S, Harbitzalléen, Oslo, Norway) The tests were removed after 48 hours and after a further 24 hours (72 hours after application of the tests) Erythema, induration and/or papules were required for a positive test.

As for the males, hand eczema during construction work with cement (chromium, cobalt)

RESULTS

Retrospective study

The test results are presented in Table 1 Of the 89 patients with a prosthesis of stainless steel, nine patients showed a positive patch test to one or two of the metals Of the 45 patients with a prosthesis made of cobalt-chromium alloy, four patients were positive to metals. Thus, altogether 134 (10 per cent) patients had a positive patch test and of these 10 had a history of metal sensitivity prior to the operation Positive patch tests were observed in 99 cases (6 per cent) with an uneven course compared with 7/35 cases (20 per cent) when there was a complicated course ($P < 0.05$) The same number of positive patch tests were observed among the co

Table 2 Number, sex and age of patients investigated

Part of investigation	Number of patients	Per cent Females	Age at operation or planned operation mean \pm s.d.
I Retrospective	134	59	61 \pm 8
II Prospective	112	65	65 \pm 9
III "Prospective" (not operated)	28	57	66 \pm 12

Table 3 Retrospective study

	Number of patients	Months between operation and patch test mean \pm s.d	Patients with positive tests to metals					Patients with history of metal sensitivity
			Co	Cr	Ni	Co and Ni	Cr and Ni	
<i>Stainless steel</i>								
complicated	71	71 \pm 17	1	—	3	1	1	5
uncomplicated	18	57 \pm 20	—	2	1	—	—	3
<i>Aluminum alloy</i>								
complicated	28	49 \pm 15	—	—	—	—	—	—
uncomplicated	17	42 \pm 32	1	2	1	—	—	■
	134		2	4	5	1	1	10

ed cases regardless of implanted metal, three and four, respectively. In no case was contact allergy to the constituents of acrylic cement found.

Prospective study

In the 112 patients in Group II, nine men, one male and eight females, were sensitive to nickel before and after the operation (Table 4). Three, who were sensitive before, showed a positive response to metal after the operation, one to nickel and two to cobalt. None of these three had a history of metal allergy. In the clinical and radiographic examination

of the hip was normal 1 year postoperatively in all cases with a contact allergy to a metal. Four cases were complicated by deep infection but all of these patients had a negative patch test.

Contact allergy to the constituents of the acrylic cement was not observed in any patient, either before or after the operation.

Of the 28 patients only tested prior to a planned operation (Group III), one man and one woman were positive to nickel. Another two women were positive to both nickel and cobalt. Moreover, one woman showed a contact allergy to methyl methacrylate.

Of all 140 patients tested before a planned

Table 4 Prospective study Patients sensitive to metals before and/or after total hip arthroplasty (Ss = Stainless steel, Co Cr = Cobalt-chromium alloy)

Sex and age	Prosthesis	Previous implants	History of metal allergy	Patch test results	
				Before	After
F 77	Ss	No	No	Neg	Nickel
M 77	Co-Cr	No	No	Neg	Cobalt
F 62	Ss	No	No	Neg	Cobalt
F 72	Ss	No	Yes	Nickel	Nickel
F 60	Co-Cr	No	Yes	Nickel	Nickel
F 60	Ss	No	Yes	Nickel	Nickel
F 75	Ss	No	No	Nickel	Nickel
F 71	Co-Cr	Yes	Yes	Nickel	Nickel
F 45	Ss	Yes	Yes	Nickel	Nickel
F 67	Ss	Yes	?	Nickel	Nickel
F 74	Ss	Yes	Yes	Nickel	Nickel
M 57	Co-Cr	Yes	?	Nickel	Nickel

operation (Groups II and III) there was a contact allergy to nickel in 11 out of 89 women (12.4 per cent) and in 2 out of 51 men (3.9 per cent). Contact allergy to cobalt was found in 2 of the 140 cases, both women being also sensitive to nickel.

A history of contact allergy to metals was given in 9 and suspected in another 2 of the 13 patients positive to a metal before operation. A history of metal sensitivity was never found in patients with a negative patch test.

DISCUSSION

Most failures following total hip arthroplasties are due to either mechanical loosening or deep infection. The differential diagnosis is based on the following: the clinical examination, the radiographic appearance (Bergström et al. 1974), the laboratory investigations, especially the ESR (Carlsson 1978, Reichelt & Brand 1975), the scintimetry (Lindberg et al. 1977b) and finally the aerobic and anaerobic cultures of tissue specimens under appropriate conditions (Lindberg et al. 1977a). There remain, however, some failures of obscure origin and in such cases intolerance for the implanted material has been suggested.

In the case of a deep infection, an increasing radiolucent zone between bone and cement and/or a localized bone resorption, sooner or later will appear (Bergström et al. 1974). However, very similar radiographic abnormalities were described by Evans et al. (1974) in connection with metal sensitivity.

Increased incidences of metal sensitivity are described in patients with failed metal-to-metal total hip arthroplasties (Benson et al. 1975, Elves et al. 1975, Evans et al. 1974, Munro-Ashman & Miller 1976), a finding not verified by Brown et al. (1977).

Implantation of metal-to-plastic total hip arthroplasty seems to imply a much smaller risk of sensitization. Benson et al. (1975) found the incidence of metal sensitivity in patients operated upon according to Charnley to be similar to that in controls.

In the retrospective part (Group I), present study, 10 per cent of the patients showed a metal allergy. Since almost all these patients had a history of metal sensitivity prior to operation, it is most probable that the allergy existed already at that time and was not induced by the surgical procedure. Probably, the same holds true for the previously published retrospective material quoted above.

The assumption of a pre-existing allergy was confirmed by the results in the prospective material groups II and III. Before operation, 12 per cent of the female patients and 4 per cent of the males had a contact allergy to nickel and most of them also a history of metal sensitivity. The figures are very high for a population in principle without skin disease. They should be compared with the incidence of nickel allergy in our control material (unpublished). In 1978 this incidence was 11.0 per cent (14.3 per cent in females and 4.6 per cent in males).

The present results naturally raise the question of the frequency of metal allergy in a healthy population. In a study on 202 healthy twins above 40 years of age, Forsbeck (1968) found 12 cases of nickel allergy (6 per cent) and one case of cobalt allergy (0.5 per cent). In 1978 a female hospital internist (1978) studied a female hospital material excluding dermatologic cases. Among 100 patients representing all adult ages, history and clinical examination showed a contact allergy in 9.4 per cent. A similar figure was found by Prystowsky et al. (1978) when testing 1158 healthy subjects. Obviously, the occurrence of metal allergy in patients with hip arthroplasty may be mainly an expression of the incidence in the healthy population.

In the prospective part of our investigation (Group II) changes from negative reactions for metals to positive reactions postoperatively were observed in three cases. Patients became positive for nickel and patients 1 and 3 for cobalt (Table 4). As regards patient no. 3, the positive cobalt reaction was caused by the implant since it was of stainless steel and therefore did not contain cobalt.

likely explanation for the change in this is the sensitization by testing or by a booster effect on a subclinical allergy. The risk of sensitization by patch testing is generally considered as being low in the majority of substances. When testing with nickel, however, there is, according to Agrup (1968) a definite risk of sensitization where nickel and chrome are concerned, but, on the other hand, not with nickel.

In cases nos. 1 and 2, the patients have become positive for a metal, which was an integral part of the prosthesis. Sensitization booster effect by earlier testing cannot be excluded. Moreover, there is naturally also the possibility that these patients, in line with case no. 3, may have been sensitized during the time interval between the tests by exposure to the allergen in the environment. In the results we obtained when attempting to sensitize guinea pigs to potassium chromate and methyl methacrylate by injections into the knee joints (unpublished), there is doubt on whether delayed-type allergy can be induced by material used in connection with total hip replacement. None of the 40 animals became sensitized. In

about 15 per cent of the animals (Magnusson & Lignman 1969).

According to Deutman et al (1977), development of metal sensitivity is rare if metal-to-plastic arthroplasties are used. Our data make it doubtful whether sensitization occurs at all. Development of contact allergy to the acrylic cement following total joint replacement was not observed by Deutman et al (1977) or by us.

The clinical implications of a pre-existing metal sensitivity are still doubtful. Since negative patch tests were slightly more frequent among complicated cases than among uneventful ones, an allergic reaction to the metal may have played a part. However, in cases except one, infection or mechanical loosening may very well explain the failures. Still more is known, especially from long

term follow-up prospective studies, we recommend that a dermatologist be consulted in cases of known or suspected metal allergy, and the prosthetic material be chosen with regard to the test result. To patch test all patients undergoing total joint replacement, as suggested by Deutman et al (1977), seems for practical reasons unrealistic.

In cases of metal sensitivity, a prosthesis made of titanium alloy is recommended. However, stainless steel is a suitable material in patients with an isolated allergy to cobalt, and a cobalt-chromium alloy is an alternative in cases of isolated nickel allergy.

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STUDY OF THE ARTERIAL SUPPLY OF THE PATELLA I THE NORMAL STATE, IN CHONDROMALACIA PATELLAE AND IN OSTEOARTHRISIS

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The arterial supply to the patella has been studied in 21 specimens. Fifteen were obtained at autopsy and six at amputation. Nine of the specimens were normal, six were diagnosed as chondromalacia patellae and six as osteoarthritis. Micropaque was injected into the arteries, and the Spalteholz clearing technique was used. Radiography was also performed. In addition to previously reported observations, arteries were found to penetrate into the patella from the interior of the quadriceps tendon, from the synovial tissue and from the medial and lateral retinaculae. Moreover, it was found that with increasing degree of cartilage destruction the arterial pattern within the patella became disturbed and irregular with formation of anastomoses.

Key words: patella, arterial supply, chondromalacia patella, osteoarthritis, changed arterial network.

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Chondromalacia patellae, which is the common term for a sequence of morphological events in the patellar cartilage, such as oedema, fibrillation, erosion and fragmentation, can appear in childhood. It becomes more common in the teens and may be regarded as the prelude to osteoarthritis of the patellofemoral joint (Perkins 1961).

Despite it being a frequently occurring phenomenon, which according to O'Donoghue (1956) has been found in more than 65 per cent of 350 arthrotomies, chondromalacia patellae has attracted little interest with regard to its pathophysiological aspects, such as, for example, vascular supply, physical properties with special attention to the hardness of the subchondral bone and intra-osseous pressure.

For this reason we have made a study, the object of which has been to analyse further the above mentioned pathophysiological aspects. A report will be given on the arterial supply of the patella under normal conditions, in chondromalacia patellae and in osteoarthritis of the patellofemoral joint.

PREVIOUS STUDIES

Arterial supply to the normal patella

Previous studies on the arterial supply to the normal patella have been published by Crock (1967), Scapinelli (1967) and Brookes (1971). Scapinelli's observations will in part be cited. Six of the main joint arteries act as channels of blood supply to the patella and

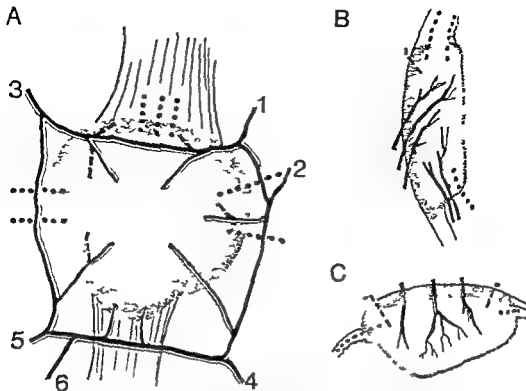


Figure 1A, B, C Schematic drawings of the patella with arterial supply in three planes. 1-6 are main joint arteries ——— represents prepatellar branches entering the bone near its margin —·—·— represents peripatellar branches (previously not described) entering through the margins of the

these are (Figure 1)

- 1 The supreme genicular artery,
- 2 the medial superior genicular artery,
- 3 the lateral superior genicular artery,
- 4 the medial inferior genicular artery,
- 5 the lateral inferior genicular artery,
- 6 the anterior tibial recurrent artery

The above arteries form the sources of an extra-osseous and an intra-osseous arterial supply to the patella.

Extra-osseous or extrinsic arterial supply

The superior arteries give off descending parapatellar branches, superior transverse branches and prepatellar branches. The inferior arteries give off ascending parapatellar branches, inferior transverse branches and prepatellar branches. The parapatellar and transverse branches give rise to an arterial ring which surrounds the

patella. The inferior part of the ring transverse infrapatellar artery runs posterior to the patellar ligament. The other part of the ring and the prepatellar arterial net lie in the thin layer of loose connective tissue which covers the dense fibrous extension of the quadriceps tendon.

Intra-osseous or intrinsic arterial supply
There are two main systems of which are represented by the mid patellar arteries. These come from the prepatellar network. These arteries enter the patella through the upper part of the anterior surface obliquely below upwards and are distributed to the chondro-osseous junction in the upper part of the patella. Recurrent branches run back to supply the anterior cortex.

The second system is represented by the arteries which come from the infrapatellar artery. The apical arteries from

deep surface of the apex of the patella between the attachment of the ligamentum ellae and the articular surface. They run upwards supplying the lowest part of the ella and communicate within the bone in branches of the mid-patellar arteries. Scapinelli (1967, 1968) stated that there is a lack of vascular penetration around the margins of the bone where tendinous and amentous structures inserted.

Arterial supply in chondromalacia patellae and osteoarthritis

It has not been possible to find any description of the arterial supply in chondromalacia patellae. Without particular reference to the patella Scapinelli (1968) stated that the principal changes in senile knees are rheosities and decreased calibre of the arteries, decreased intra-osseous vascularity and ruptures.

MATERIAL

The arterial supply to the patella was studied in 15 specimens, of which six were obtained at amputation of the lower limb for neoplastic disease not involving the knee joint and 15 at autopsy. Peripheral vascular disease was not the cause of death. The ages of the individuals varied from 17 to 70 years and the mean age was 34 years.

METHOD

As contrast medium for the injection of arteries a mixture of one part Micropaque and two parts 10 per cent formaldehyde solution was used.

Material obtained at amputations (7 specimens)

The injection was given by hand in the femoral artery at a distance of at least 10 cm from the bifemoral joint space. The injecting was done after the specimen had been stored for 24–36 hours at room temperature according to Mullinger & Trueta (1970). The injection was continued for 6 hours and all leaking vessels were tied off.

The pressure was about 150 mmHg and this was maintained by a pressure unit for 24 hours during which time the specimen was stored in formaldehyde solution. After this time the pressure had decreased only a few mmHg. Some 300–500 cm³ of contrast medium was injected into each specimen.

Material obtained at autopsy (15 specimens)

- In two specimens the same procedure was carried out as for the amputation material.
- Six specimens were deep frozen immediately following their excision. Injections were performed as in the amputation material when the specimens were thawed.
- In seven specimens a different procedure was carried out. Before taking out the specimen the femoral artery was dissected in the cadaver. A catheter was introduced with its tip 10 cm above the tibiofemoral joint space. Twenty centimeters of the thigh was covered by an Esmarch bandage. The time for filling was 1–1.5 hours after which the pressure unit was applied and left in the cadaver for some 12 hours. After resection the specimens were stored in formaldehyde solution.

The specimens were deep frozen as this facilitated the cutting up of the specimens into about 7–10 mm thick slices. Twelve specimens were divided in the sagittal plane and nine specimens in the transverse plane. Previous experience had shown that the slicing of the specimens made the study of the topographic anatomy of the arteries much easier (Peterson et al 1974). After thawing and decalcification the slices were radiographed, in eight specimens radiography of the slices was also carried out before decalcification.

The Spatheholz clearing procedure was also performed (Crock 1967).

RESULTS

Arterial supply to the normal patella (n=9)

Earlier investigations could be verified. In addition the following observations were made which have not previously been described.

I Extrinsic arterial supply

- On sagittal sections in five cases arteries were observed to penetrate into the base



Figure 2b The upper half ($\times 5$) of the patella illustrated in Figure 2a containing the MPA. The arteries of the quadriceps tendon pass the base of the patella into its interior. Arteries from the synovial tissues (SA) also penetrate the interior of the patella.

Figure 2a. Sagittal section of a normal patella from a 63-year-old man. Radiograph after decalcification. At top, quadriceps tendon (Q). Dominating mid patellar arteries (MPA) and small apical arteries (AA) ($\times 2$)

of the patella from the interior of the quadriceps tendon (Figure 2A and B). Moreover, arteries running superficially, anterior to the quadriceps tendon, were seen to enter into the proximal part of the patella (Figures 2B and 6)

- (b) On transverse sections the medial part of the peripatellar arterial ring was located deep to the patellar retinacula.
- (c) On transverse sections arteries were seen to penetrate the anterior surface of the patella close to the retinacular insertion on the medial side and occasionally on the lateral side.
- (d) On transverse sections arteries were seen to penetrate the patellar margin on both the medial and lateral sides. These arteries arose from arterial networks located posteriorly in the synovial tissue and on the posterior surface of the retinacula (Figure 3).
- (e) On sagittal sections a rich net of arteries could be demonstrated to arise from the arteries in the synovial tissue at its attachment to the patellar base (Figure 2B) and apex. These arteries penetrated into the interior of the patella.



Figure 3 Transverse section of a normal patella from a 27-year-old woman. The medial retinaculum (M) insert to the left. Radiograph after decalcification.

Numerous mid-patellar arteries thinning into filamentous arteries radiating towards subchondral area.

Medially some small arteries penetrate the coracoid bone into the interior. Laterally, a small artery (*) arises from an arterial network in the medial retinaculum and penetrates into the bone beneath the cartilage.

Intrinsic arterial supply

The appearance irrespective of age, of the apical and mid-patellar arteries varied from case to case. In some cases, apical arteries were conspicuously large and traversed the patella towards its base and on their way a number of small arteries were given off (Figure 4). In these cases, the contribution from the mid-patellar branches was not as pronounced as was noted in other cases in which the mid-patellar arteries were larger and the apical arteries were limited to the apex of the patella. In the latter case, the main apical arteries were conspicuously narrow (Figure 2A).

The subchondral arteries arose from the apical and mid-patellar arteries as straight or slightly curved branches and radiated towards the subchondral region. The arteries divided by dichotomy or branches were given off irregularly. In all specimens with normal cartilage the



Figure 4 Sagittal section of a normal patella from a 22-year-old man. Radiograph after decalcification. At top quadriceps tendon (Q). Apical arteries (AA) are dominating in the subchondral region almost up to the base of the patella.

calibre of the arteries gradually diminished into fine terminal endings.

In specimens from persons aged 60 and above, the main arteries were much thinner than the corresponding arteries in the younger specimens. Moreover, the terminal endings did not reach out as far towards the periphery as compared to those in the younger specimens.

Arterial supply in chondromalacia ($n=6$)

Before the specimens were sectioned, a grading of the degenerative change was made (Collins 1949)

Grade 1 fibrillation three specimens
Grades 2 and 3 fissures and fragments three specimens
Grade 4 none

The extrinsic arterial supply resembled that of the normal patella

The distribution of the apical and patellar arteries inside the patella resembled that of the normal. In their course to the chondral bone some of the peripheral arteries did not become thinner but rather retained the same calibre as the arteries from which they arose. The subchondral arteries had principally two different appearances. There were arteries which reached a cartilage with normal cartilage and resembled those of the normal patella, and arteries which, reaching the zone of degenerated cartilage, became wider. They reached further towards the periphery and ended either straight and abruptly or were bent along parallel to the cartilaginous surface. Within the degenerated zone it was occasionally observed that the arterial pattern had an arcade-like design. Within these arcades the arteries were tortuous and remarkably wide at the peripheral margin (Figure 5). A correlation could be made with the grading of the cartilage degeneration. In Grade 1 the arterial design was only suggestive of the above described arterial pattern, whereas in Grades 2 and 3 it was fully pronounced.

Arterial supply in osteoarthritis ($n=6$)

The arterial pattern of the extrinsic arterial supply was the same as in the normal patella, irrespective of osseous changes.

In general the design of the intrinsic arterial supply resembled that of Grades 2 and 3 in chondromalacia patellae. In cases with severe osteoarthritis the type of arterial changes were the same as in chondromalacia



Figure 5. Sagittal section of a patella with chondromalacia Grade 3 from a 21 year-old man. Radiograph after decalcification. Chondromalacia (C) in central part of articular cartilage. In this region the arteries are coarser than normal in their subchondral course where they form a number of anastomoses (*) and run along the osseochondral border.



Fig. 6. Sagittal section of a patella with osteoporosis from a 63-year-old man. Radiograph decalcification. Degenerative changes (D) are diffusely in the cartilage. Arteries towards the osseochondral junction are coarse and wide. They have a tortuous course and form anastomoses.

late but the degree was much more pronounced (Figure 6).

DISCUSSION

The findings of previous studies on the arterial supply to the patella by Crock (1967)

and by Scapinelli (1967, 1968) have also been observed in this study. In addition to previously reported observations this study has disclosed some details which might have some functional importance. The parapatellar artery running along the medial border of the patella has been found to be located posterior to the medial fibrous structures and not as suggested by Scapinelli (1967, 1968) on the superficial fascia. In a number of cases the anterior mid patellar arteries have penetrated the cortex close to the medial, lateral and proximal patellar border. Arteries have been demonstrated to penetrate from the quadriceps tendon and from the synovial tissue into the base of the patella. Moreover arteries have been demonstrated to penetrate from the synovial tissue on the retinacula through both the medial and lateral patellar borders. It has thus become obvious in this investigation that some of the arteries penetrating the medial superior and lateral borders of the patella have their origin in deeply situated peripatellar arteries and thus do not arise from the superficial arterial circle. Our observation of the penetration of arteries into the patella at its borders does not coincide with the observations of Scapinelli. We have not been able to find any reason for this difference in observations. Crock (1967) described the mid patellar and apical arteries but did not mention any other arteries penetrating into the patella. However on examining the figures in Crock's monograph it is obvious that there are other arteries penetrating into the patella and in particular this is obvious in a patella from a 9 year-old child which contains two large arteries penetrating the medial border posterior to the fibrous capsule. It may be speculated that these peripheral arteries which penetrate into the patella may be of some importance in the healing of patellar fractures. One method of treatment is to use a circular wire for reduction of the fracture and possibly this wire can strangle the arteries penetrating into the patella and thus disturb the circulation of the fracture fragments.

The distribution of the arteries inside the patella has previously not been described in detail. It became obvious that with an increasing degree of cartilage damage there was a corresponding change in the arterial architecture. An interesting observation was that these arterial changes were limited to the region of the bone covered by the central part of the cartilage destruction. The arterial change seemed to follow the same pattern both in chondromalacia patellae and in osteoarthrosis. It is thus obvious that in articular degeneration there is a vascular change which in degree seems to correspond to the severity of cartilage destruction.

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THE LEG SWING THROUGH GAIT USING TWO CRUTCHES

Analysis of the Ground Reaction Forces and Gait Phases

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Using a Force Plate the gait cycle for one leg swing-through gait of ten normal subjects on Canadian crutches was monitored, and a composite diagram of forces on the lower limb and both crutches was produced. In addition the relationship of the stance and swing phase for both the lower limb and crutches was studied and the percentage of these phases and their overlap included on the composite diagram.

The average maximum vertical ground reaction to the leg was 1.32 body weight, 16 per cent higher than that reported for normal walking. The horizontal force on the lower limb in the direction of walking was 0.35 body weight, compared to 0.15 for normal walking.

Vertical ground reaction to crutches was on average 0.54 body weight on the side of the landing leg and 0.51 on the contralateral side.

Horizontal ground reaction on the crutches at right angles to the direction of ambulation was 0.09 body weight on the right and 0.08 on the left.

The results were considered to indicate caution in the prescription of one leg swing-through gait in subjects with diseased bone and joints in the lower limb.

Key words: crutches, gait.

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This work has been done on lower limb ground reaction forces in normal walking, explained by Elftman (1939) and Jacobs et al (72), and on the interrelationship of the various phases of the gait cycle by Murray (67). However, the nature of the gait cycle during swing-through crutch walking has been largely ignored. Although Shoup et al (74) reported on the mechanics of crutch walking and showed displacement of body segments in different planes, forces and phase relationships were not observed. Stallard et al (1978) monitored the increase in vertical

ground reaction in swing-through gait on 10 normal subjects, but did not report on horizontal reactions on the lower limb, the ground reaction to crutches or on phase relationships.

The nature and magnitude of the forces developed, and the relationship of the various limb and crutch phases could have important repercussions for aged or infirm patients for whom one leg swing-through gait might be prescribed due to injury or disease of a lower limb. Consequently a study was undertaken to establish the pattern of forces developed in

one leg swing-through gait, using normal subjects who were familiar with this form of ambulation

MATERIAL AND METHODS

Ten normal adult volunteers were used (5 males and 5 females). The average weight of the subjects was 670 N, average height 1.74 m, average age was 35 years and each had right hand predominance. All subjects were members of staff of the Unit, and this enabled 2 weeks of practice on the Canadian crutches (with 45 mm diameter rubber tips) used for the trials to be undertaken prior to the commencement of the study.

Ground reaction forces were monitored on a Kistler 9261 A Force Plate, mounted in the centre of a 9 m long \times 3 m wide non slip conductive rubber walkway and connected to a Kistler 9803 Electronic Unit which in turn fed an SE 2800 multichannel UV recorder — the resonant frequency of the system being in excess of 200 Hz. During a separate trial of the same subjects, single leg stance and swing phase times for the subjects and crutch swing phase and grounded times were simultaneously monitored by means of a multichannel digital multiplex transmitter. This was activated by double copper strips placed parallel

in order to complete a circuit through the conductive walkway. This system fed the multichannel UV recorder used at a paper speed of 50 mm/s, indicating foot stance and crutch grounded times by means of the on-off condition of the individual channels assigned to each. The two parts of the study were separated only

because there were insufficient channels on the UV recorder for simultaneous recording. Three subjects were unable to take part in the second part of the trials.

Prior to the commencement of the representative runs at each individual's

Plate, each subject was given as much practice as he required to ensure assured landing of or relevant crutch on the Force Plate. A subject was considered representative only when both subject and the researchers were satisfied that the subject's usual gait pattern conformed to the subject's usual subject wore their normal shoes, none of which had excessively high heels.

Chosen speed for each subject was measured during the trials to determine crutch relationship by means of two photocell switches placed 6 m apart in the centre of the walkway, connected to a digital timer which started by the first and stopped by the second.

RESULTS

Table 1 shows the weight, height, age and sex of the individuals used. All had right hand predominance and elected to land on the right leg.

The lower limb ground reaction forces for each individual were analysed in terms of the first Fz peak, the trough of Fz and the second Fz peak, the maximum positive Fy, the negative Fy on the lower limb, together with the maximum crutch Fz, positive and negative Fx. Average results for each subject

Table 1 Details of subjects

Name	Age	Body weight (N)	Height (m)	Sex
JT	30	828	1.79	M
IF	32	606	1.74	M
RR	26	717	1.70	F
ED	35	728	1.76	M
JS	39	686	1.75	M
MN	39	615	1.68	F
EH	23	641	1.73	F
DD	52	824	1.81	M
JD	41	690	1.73	F
TD	33	561	1.69	F
Av	35	Av 670	Av 1.73	5 Males 5 Females

in Table 2, together with the standard deviation of each individual's five runs. From the results overall averages were computed (shown at the bottom of Table 2) so that a composite diagram for F_z , F_y and F_x for the lower limb and crutches could be drawn (Figure 1). The average ratio of swing and stance phase times for the lower limb and crutches were also calculated and the results for each subject, together with their standard deviations are shown in Table 3. Overall averages and standard deviations are listed on the last line of this table, and these were also used in the construction of the composite force diagram in Figure 1.

The speed of crutch walking for each individual was averaged over five runs and the results are shown in Table 3, together with standard deviations, the last line showing the overall average and standard deviation.

Figure 1 shows the overall averages of all forces and the interrelation of the gait cycles. Some subjects exhibited maximum force on the first peak, others on the second, all conformed to the general pattern of a Horizontal ground reaction forces on the lower limb in the direction of walking reaching a maximum during the first half of the stance phase and then reverse during take-off during swing through.

Since body weight is shared between two crutches, ground reaction forces on each are lower than those experienced by the lower limb. All subjects used their right leg for single leg landing, but two recorded lower average values on the left crutch for vertical ground reaction, seven higher values on the right and one recorded identical values on right and left crutches.

The average horizontal ground reaction forces on the crutches, in the line of walking, reached a maximum during the first half of the stance phase on the right and on the left and in the second half of stance phase the average peak reversed direction and reached a lower value on the right and left crutches. The horizontal ground reaction force at right angles to the line of ambulation (F_x) was typically higher on the right than on the left.

The average of the maximum peak for vertical loading on the lower limb for males was 1.45 compared to 1.27 for the females, and this was the case both for those whose height was above 1.73m and those who were 1.73m or less. Average peak for vertical loading on the lower limb was virtually identical for those aged 35 years or above and those aged less than 35 years, and no correlation between this value and average speed could be discerned.

Double support time (with both the one leg and the crutches grounded) occurred in two phases of each gait cycle:

- with the crutches in front of the body prior to swing through (DS1 Table 3)
- with the crutches behind the body after single leg landing (DS2 Table 3)

Swing through walking speed was an average of 1.44 m/s for all individuals. Some individuals had a very consistent performance others were more erratic, and standard deviations (Table 3) indicated the degree to which this occurred in individuals. As might be expected, there were marked differences in the speeds of different subjects, as indicated by the comparatively high standard deviation on the average figure.

DISCUSSION

Ground reaction forces to the subjects' lower limbs were seen to follow the same general pattern as observed in normal walking (exemplified in papers by Elftman (1939) and Jacobs et al (1972)) in that the vertical force F_z peaked early in the cycle, dipped in the middle and peaked again towards the end of the cycle. Horizontal forces in the direction of ambulation (F_y) also followed the classic pattern observed in normal gait, in which the ground reaction is initially opposite to the direction of walking, passing through zero approximately half way through the leg stance phase and then occurring in the same direction as walking at the end of the phase. No significant reaction on the lower limb at right angles to the directions of crutch walking (F_x) was observed.

Table 2. Ground reaction forces as a ratio of body weight

Subject	Right lower limb									
	Fz					Fy				
	1st Peak		Trough		2nd Peak		Fore		Aft	
	Average	Deviation	Average	Deviation	Average	Deviation	Average	Deviation	Average	Deviation
JD	1.23	0.02	0.90	0	1.23	0.12	0.30	0.01	0.17	
EH	1.30	0.04	0.78	0.02	1.34	0.05	0.36	0.03	0.35	
RR	1.47	0.09	0.74	0.05	1.43	0.10	0.45	0.06	0.34	
JT	1.40	0.10	0.72	0.06	1.53	0.02	0.48	0.02	0.32	
DD	1.43	0.13	0.71	0.06	1.33	0.11	0.37	0.04	0.30	
ED	1.77	0.03	0.52	0.08	1.57	0.23	0.44	0.06	0.32	
MN	1.08	0.04	0.84	0.01	0.99	0.02	0.21	0.01	0.20	
IF	1.00	0	0.78	0.03	1.27	0.09	0.20	0	0.23	
JS	1.27	0.04	0.68	0.05	1.28	0.05	0.36	0.03	0.27	
TD	1.09	0.07	0.87	0.03	1.22	0.03	0.34	0.01	0.21	
Average	1.30	0.23	0.75	0.11	1.32	0.17	0.35	0.09	0.27	

	Left crutch							
	Fz		Fy				Fx	
			Fore		Aft			
	Average	Deviation	Average	Deviation	Average	Deviation	Average	Deviation
	0.63	0.03	0.09	0.01	0.02	0.01	0.09	0.01
	0.55	0.03	0.07	0.01	0.06	0.02	0.06	0
	0.51	0.04	0.10	0.01	0.05	0	0.08	0.02
	0.50	0.02	0.14	0.01	0.03	0.01	0.07	0.01
	0.51	0.04	0.10	0.02	0.09	0.01	0.04	0
	0.44	0.02	0.11	0.02	0.04	0.01	0.11	0.02
	0.46	0.02	0.09	0.01	0.03	0	0.09	0.01
	0.52	0.01	0.10	0.01	0.03	0	0.09	0.01
	0.56	0.03	0.09	0.01	0.12	0.01	0.12	0.01
	0.42	0.03	0.08	0.01	0.02	0.01	0.06	0.01
	0.51	0.06	0.10	0.02	0.05	0.03	0.08	0.03

	Right crutch							
	Fz		Fy				Fx	
			Fore		Aft			
	Average	Deviation	Average	Deviation	Average	Deviation	Average	Deviation
	0.60	0.04	0.10	0.07	0.03	0.01	0.10	0.02
	0.54	0.02	0.09	0.01	0.04	0.01	0.09	0.01
	0.51	0.01	0.08	0.02	0.07	0.01	0.09	0.01
	0.51	0.03	0.12	0.01	0.03	0.01	0.08	0.02
	0.57	0.03	0.11	0.01	0.08	0.02	0.05	0.01
	0.49	0.01	0.10	0.02	0.05	0.02	0.10	0.02
	0.50	0.02	0.08	0.01	0.04	0.01	0.08	0.01
	0.53	0.02	0.08	0.02	0.03	0	0.08	0.02
	0.63	0.07	0.10	0.01	0.12	0.02	0.13	0.01
	0.54	0.01	0.08	0.02	0.03	0	0.10	0.02
	0.54	0.05	0.09	0.01	0.05	0.03	0.09	0.03

Table 3 *Gait phase relationships*

Subject	Crutch stance		Single leg stance		1st double stance (DS1)		2nd double stance (DS2)		Speed of crutch walking	
	Average	Deviation	Average	Deviation	Average	Deviation	Average	Deviation	Average	Deviation
	%	%	%	%	%	%	%	%	m/s	m/s
JD	55.3	1.66	54.6	2.42	5.8	1.01	4.1	0.54	1.64	0.084
CH	56.6	1.20	56.6	0.94	8.5	0.66	4.8	0.70	1.64	0.028
RR	55.8	0.68	55.7	2.30	8.6	2.60	2.9	0.65	1.33	0.040
ED	55.6	2.70	54.2	1.10	5.3	3.17	4.5	1.30	1.37	0.050
IF	55.5	0.70	55.3	1.55	7.3	2.20	3.3	0.83	1.43	0.056
JS	53.7	1.07	53.2	2.30	4.6	1.32	2.3	1.27	1.49	0.038
TD	55.2	1.40	56.4	0.84	8.5	0.59	3.1	0.84	1.20	0.020
Overall average	55.4	1.60	55.1	1.60	6.9	2.34	3.6	1.20	1.44	0.162

Table 2 Ground reaction forces as a ratio of body weight

Right lower limb										
		Fz						Fy		
		1st Peak		Trough		2nd Peak		Fore		Aft
Subject	Average	Deviation	Average	Deviation	Average	Deviation	Average	Deviation	Average	Deviation
JD	1.23	0.02	0.90	0	1.23	0.12	0.30	0.01	0.17	
EH	1.30	0.04	0.78	0.02	1.34	0.05	0.36	0.03	0.35	
RR	1.47	0.09	0.74	0.05	1.43	0.10	0.45	0.06	0.34	
JT	1.40	0.10	0.72	0.06	1.53	0.02	0.48	0.02	0.32	
DD	1.43	0.13	0.71	0.06	1.33	0.11	0.37	0.04	0.30	
ED	1.77	0.03	0.52	0.08	1.57	0.23	0.44	0.06	0.32	
MN	1.08	0.04	0.84	0.01	0.99	0.02	0.21	0.01	0.20	
IF	1.00	0	0.78	0.03	1.27	0.09	0.20	0	0.25	
JS	1.27	0.04	0.68	0.05	1.28	0.05	0.36	0.03	0.27	
TD	1.09	0.07	0.87	0.03	1.22	0.03	0.34	0.01	0.21	
Average	1.30	0.23	0.75	0.11	1.32	0.17	0.35	0.09	0.27	

Left crutch							
Fz		Fy				Fx	
		Fore		Aft			
Average	Deviation	Average	Deviation	Average	Deviation	Average	Deviation
0.63	0.03	0.09	0.01	0.02	0.01	0.09	0.01
0.55	0.03	0.07	0.01	0.06	0.02	0.06	0
0.51	0.04	0.10	0.01	0.05	0	0.08	0.02
0.50	0.02	0.14	0.01	0.03	0.01	0.07	0.01
0.51	0.04	0.10	0.02	0.09	0.01	0.04	0
0.44	0.02	0.11	0.02	0.04	0.01	0.11	0.02
0.46	0.02	0.09	0.01	0.03	0	0.09	0.01
0.52	0.01	0.10	0.01	0.03	0	0.09	0.01
0.56	0.03	0.09	0.01	0.12	0.01	0.12	0.01
0.42	0.03	0.08	0.01	0.02	0.01	0.06	0.01
0.51	0.06	0.10	0.02	0.05	0.03	0.08	0.03

Right crutch							
Fz		Fy				Fx	
		Fore		Aft			
Average	Deviation	Average	Deviation	Average	Deviation	Average	Deviation
0.60	0.04	0.10	0.07	0.03	0.01	0.10	0.02
0.54	0.02	0.09	0.01	0.04	0.01	0.09	0.01
0.51	0.01	0.08	0.02	0.07	0.01	0.09	0.01
0.51	0.03	0.12	0.01	0.03	0.01	0.08	0.02
0.57	0.03	0.11	0.01	0.08	0.02	0.05	0.01
0.49	0.01	0.10	0.02	0.05	0.02	0.10	0.02
0.50	0.02	0.08	0.01	0.04	0.01	0.08	0.01
0.53	0.02	0.08	0.02	0.03	0	0.08	0.02
0.63	0.07	0.10	0.01	0.12	0.02	0.13	0.01
0.54	0.01	0.08	0.02	0.03	0	0.10	0.02
0.54	0.05	0.09	0.01	0.05	0.03	0.09	0.03

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ACTURES OF THE CERVICAL SPINE PATIENTS WITH ANKYLOSING SPONDYLITIS

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Fractures of the cervical spine in six patients suffering from ankylosing spondylitis are presented. Three patients had a hyperextension type of injury. These fractures were extremely unstable and combined with spinal cord damage. In the other cases the fracture was caused by a flexion mechanism. These fractures were stable and there was no damage to the spinal cord. Treatment modified according to the demands of the fractures is outlined.

Key words: ankylosing spondylitis, cervical spine, fracture, treatment

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Fractures of the ankylosed cervical spine are rather uncommon. Our review of the relevant literature revealed that since the publication of Stasny (1933), only 60 cases have been reported. Furthermore, most authors have reported only one or a very few patients (Jorgensen 1949, Janda et al 1968, Klems 1970, Osgood et al 1973). Based on our experience with six such cases, it is our purpose to point out the therapeutic difficulties encountered in the management of these fractures.

PATIENTS AND METHODS

During the years 1972-1978, six patients with ankylosing spondylitis (AS) were admitted to our department for fractures of the cervical spine. Five of the six patients had been treated for AS before the fracture occurred, the sixth was unaware of the disease. All were males.

The characteristics of the patients and the type of trauma are summarized in Table 1. With respect to the direction of the forces causing the cervical fracture and to the involvement of the spinal cord, we distinguished two fracture groups in our patient population.

A The first group (patients 1, 2 and 3) was characterized by spinal cord damage which occurred either at the time of the accident (patients 1 and 2) or during the course of the treatment (patient 3). In all patients the fractures resulted from a force applied to the forehead (Figure 1). The fractures occurred in what had formerly been the intervertebral space rather than through the vertebral body itself (Figure 2A and B).

B The second group (patients 4, 5 and 6) was characterized by absence of spinal cord damage. Cervical fractures in two patients (5 and 6) resulted from a flexion injury. In the third patient (4), with no recollection of the accident, the roentgenological picture of the fracture was also clearly indicative of a flexion injury (Figure 3A and B). The accident caused a wedge-like compression of the vertebral body and fracture of the articular facets.

Patients 1 and 2 were transported to the hospital immediately after the accident, supine with the head placed horizontally. In this position they complained of severe pain and increasing muscle weakness. This was relieved when the ambulance personnel placed the patients' heads in flexion (Figure 2A and B).

Patient 3 was transported supine with his head kept in flexion by a special vacuum cushion (Figure 4). This position was maintained during the roentgen examination and application of the halo-vest apparatus.

Table 1 The characteristics of the AS patients and the type of trauma causing cervical

Case no	Age	Accident	Type of injury	Level	Neurological on admission
1	56	automobile	hyperextension	C 5-6	central cord
2	59	automobile	hyperextension	C 4-5	complete
3	67	automobile	hyperextension	C 6-7	normal neurolog
4	42	automobile	flexion	C 5-6	normal neurolog
5	78	fall backwards	flexion	C 2-3	normal neurolog
6	72	fall backwards	flexion	C 7 Th 1	normal neurolog



Figure 1 Patient 2 The direction of the traction in the halo ring is upright to maintain the head and neck in flexion Note the contusion of the patient's face

Patients 4, 5 and 6 sought medical advice because of persistent neck pain 4, 7 and 10 days after the accident respectively.

Our routine treatment aimed to restore the alignment of the neural canal as soon as possible by means of closed reduction combined with skull traction. This was successful in five patients. In patient 6 the fracture-dislocation could not be reduced at all despite intensive skull traction. Taking into consideration this patient's age (72 years) open reduction was considered dangerous and the fracture was left to heal unreduced.

Patient 1 was treated with skull traction until the fracture united. In all other patients the fracture was immobilized by means of a halo-vest apparatus. This immobilization failed in two patients.

In patient 2 the fracture redislocated immediately on the patient being placed in the halo-vest apparatus. The reduction could be maintained only by a continuous almost vertical traction on the halo ring (Figure 1) until the fracture healed.

In patient 3 the dislocation was reduced and immobilized in the halo-vest apparatus on admission. One week later suddenly became paralysed in all four limbs during his sleep. Traction on the halo ring was applied immediately instead of the halo-vest immobilization. Tetraplegia then resolved during the next 24 hours. A roentgenogram made immediately after the start of the traction showed only a slight anterior dislocation at the site. Traction was continued for a further 4 weeks and the fracture healed without complication.

Patients 4, 5 and 6 had their cervical spine immobilized in the halo-vest apparatus for 12 weeks. This was followed by support in a special brace for a further 6-8 weeks.

RESULTS

Roentgenograms showed that all fractures were solidly healed 3 months after injury.

Patient 1, with clinical signs of central cord syndrome on admission, had complete return of muscle activity in all 4 limbs within 6 months after the accident. The complete tetraplegia in the other patients persisted despite 6 months of intensive rehabilitation.

Patients 3, 4, 5 and 6 complained of occasional vertebral pain at the chest level 6 months after the accident. None of them showed any sign of spinal cord damage.

DISCUSSION

The ability to recognise two types of cervical fractures (hyperextension and flexion) of cervical fractures in AS is important for



FIGURE 2 A and B Patient 1 (A) Lateral roentgenogram demonstrating a fracture at the C6-C7 level. The complete fracture separation is mainly caused by placing the patient's head on the X-ray table without support. (B) Fracture healed after 3 months.

ional approach to treatment. In our patient series we could distinguish hyperextension fractures as a distinct entity with a greater risk of spinal cord damage as compared with flexion injuries sustained by flexion force in ankylosed cervical spine.

Two important points as to the treatment of patients with hyperextension injuries of the ankylosed cervical spine must be considered.

Recommendations of emergency treatment of cervical spine fractures stating that the patients should be placed horizontally face upward on a firm surface (Palma 1970) do not apply here. One must appreciate that the neutral position for the patient with AS and cervical spine fracture usually means maintaining considerable flexion of the head and neck to conform to the patient's spinal axis prior to injury (Figure 1).

Hyperextension at the fracture site causing further spinal cord damage may occur during the transport (Rogers 1957, our patients 1 and 2), during the roentgenological examination (Burke 1971, Figure 2A), during the treatment if skull traction is applied in the horizontal direction (Osgood et al 1973), and in every other instance when the patient is placed horizontally without head support on a firm surface. To prevent this a special cushion (Figure 4), which can be individually fitted to the shape of the patient's spinal kyphosis, proved to be very useful.

2 These fractures are particularly unstable because many of the normally supportive cervical soft tissues and ligaments are themselves calcified and, therefore, also fracture at the time of injury.

Several instances of patients becoming paralysed while in traction or in inadequate

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THE RESULTS OF INTERTROCHANTERIC OSTEOTOMY IN ADVANCED OSTEOARTHRITIS OF THE HIP

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The results are presented of 50 intertrochanteric osteotomies after a minimum observation time of 9.3 years. This method of treatment was found to be of lasting benefit in 86 per cent of the patients. The results encourage us to consider osteotomy also in younger patients with osteoarthritis.

Keywords hip joint, methods, osteoarthritis, osteotomy

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Intertrochanteric osteotomy is a well established form of surgical treatment for osteoarthritis of the hip joint. McMurray (1935) was the first to perform and publish a series of displacement osteotomies for osteoarthritis of the hip. The literature contains a large number of subsequent reports which all include that the result is favourable in the majority of patients (Adam & Spence 1968, Cohen et al 1972, Goldie et al 1973, Gudmundsson 1970, Gudmundsson et al 1970, Hansen et al 1973, Harris & Kirwan 1964, Jerre & Tilling 1969, King & Dooley 1972, Mendes 1975, Morscher 1971, Olsson 1974, Salenius et al 1971).

Since the introduction of total hip replacement, the primary results of which are so strikingly good, osteotomy has fallen somewhat into the background. Because of a well founded fear of late mechanical loosening of the prosthesis, we feel it would be of value to examine the long term results of a series of osteotomies reported earlier (Gudmundsson et al 1970).

PATIENTS AND METHODS

In 1970 Gudmundsson et al published the results of 100 medial displacement osteotomies done for advanced osteoarthritis of the hip. The medial displacement of the osteotomies varied between 13 and

19 mm. No wedge osteotomies were performed. Stable internal fixation was achieved with a device (Figures 1-3) designed by Jerre (Jerre & Tilling 1969). There were 64 patients and the operation was performed in 68 hips. Before the osteotomy 97 per cent of the patients had pain at rest and 100 per cent had pain on weight-bearing.

The present long term follow-up study involves 47 patients with 50 operated hips, 11 patients have died, 3 have had the osteotomy converted to total hip replacement and 3 patients are lost to follow-up. The follow-up period averaged 10.1 years (range 9.3-11.4 years).

We have evaluated pain in the same way as

The radiological examination consisted of a standard frontal and lateral projection with the patient in the supine position. The joint space was measured laterally on the frontal view along a line which was the direct continuation of the supra-acetabular part of the ilium to the femoral head.

The radiological diagnosis of osteoarthritis was based on the presence of cysts, sclerosis and narrowing of the joint space. All hips had

RESULTS

Table 2 demonstrates that 74 per cent (37/50) of the hips do not give rise to pain at rest



Figure 1 Hip with advanced osteoarthritis prior to osteotomy

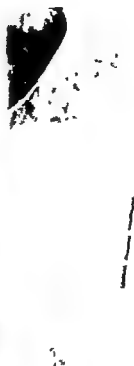


Figure 2 Same hip immediately after osteotomy

after 10 1 years and that a further 14 per cent (7/50) still have less pain at rest than before operation. Eighty-eight per cent (44/50) of the patients are thus improved as far as pain at rest is concerned. Forty per cent (20/50) of the patients are free of pain on weight-bearing and a further 46 per cent (23/50) are improved, i.e. 86 per cent (43/50) are improved as far as pain on weight-bearing is concerned.

The range of movement in our series was compared with that reported by Goldie et al (1973) with an observation time 8.7 years (Table 3). The average number of points before operation was 3.7 and at follow-up 3.2. Table 4 shows that 72 per cent (34/47) of the patients could walk more than 500 meters without resting. Most (37/47) managed well without a stick or used one outdoors (Table 5). Eight patients had a leg shortening of

more than 2 cm, 15 between 1 and 2 cm, 24 less than 1 cm. Twenty-six patients walked without a limp or with only a slight one, whereas 21 walked with a marked limp.

Twenty-five of the patients, including housewives, returned to the work they did before the operation and are still working. Now they have become eligible for old age pension. Three changed to lighter work, nine became retired at the time of surgery. We evaluated especially about the ability to put on and take off shoes and compared the results with those of Olsson (1974) and Danielsson (1973) as demonstrated in Table 6.

The patients' own evaluation was compared with the patients' evaluation reported in Olsson (1974) and in Goldie (1973) (Table 7). The patients were asked if they would still want to have an osteotomy.

Table 1 Age at operation

Years	31-40	41-50	51-60	61-70	71-80	Total
No of patients	3	7	17	19	1	47



Fig. 1. Same hip 10 years after the osteotomy.

ed, if the circumstances were the same as at the time of surgery. Eighty-four per cent (46/50) said they would

patient developed a late infection 8 years after the osteotomy, no other late complication was encountered.

Table 8 shows that 46 per cent (23/50) of patients had regression in the femoral head and acetabulum. The regression was more evident in the femoral head than in

Table 2. Pain.

	Pain at rest		Pain on weight bearing	
	No. of hips	%	No. of hips	%
No pain	37	74	20	40
Less pain	7	14	23	46
Unchanged	4	8	2	4
Worse	2	4	5	10
Total	50	100	50	100

the acetabulum. The correlation between pain relief and regression of radiological changes is shown in Tables 9 and 10. The pain relief was more pronounced in cases with obvious radiological regression.

We measured the joint space on the X-ray taken immediately after the osteotomy and on a second X-ray taken 10 years after the operation. The mean joint space was 1.34 mm before the operation and 2.22 mm after 10 years. This is a statistically significant difference (t test $P < 0.001$).

DISCUSSION

The present series is a long term follow-up of 50 intertrochanteric osteotomies with a mean observation time of 10.1 years. We have not been able to find a report of a series with a comparable observation time.

Table 3. Range of movement.

Points	Present Series				Goldie et al (1973)
	Before op		After op		
	No. of hips	%	No. of hips	%	%
0	1				7.5
0	2	3	9	18	16
0	3	14	21	42	32
0	4	26	15	30	33
0	5	14	5	10	7.5
0	6				4
	50	100	50	100	100

Table 4 Ability to walk

Distance in meters	No of patients	%
100	3	7
101-500	10	21
501-1000	7	15
1001	27	57
Total	47	100

Table 5 The use of a stick

	No of patients	%
None	21	45
One outdoors	16	34
One always	6	13
Two always	4	8
Total	47	100

Olsson (1974) compared osteotomies done with a non-compressive method and those done with the AO compressive method and McKee-Farrar total hip replacement. The points scored for pain in these three series were 4.3, 4.3 and 4.5. In the present study 74 per cent (37/50) had no pain at rest and 40 per cent (20/50) had no pain on weight-bearing. In 1970, 83 per cent of the patients were free of pain at rest and 88 per cent on weight-bearing. These results are in accordance with those of Goldie et al (1973), where the average observation time was 8.7 years. The results are better than non-

Table 7 The patients' own evaluation

	Present Series No of hips	%	Olsson (1974) %	Goldie (1973) %
Worthwhile	42	84	88	84
Not worthwhile	8	16	12	16
Total	50	100	100	100

operative treatment alone as reported Danielsson (1964), who obtained improvement in 59 per cent (70/119) of cases. It should be emphasized, however, in connection with the results of nonoperative treatment as reported by Danielsson, that 11 per cent (15/119) of his patients had never felt hip pain. The range of movement diminished from 3.7 points to 3.2 points at follow-up. 28 per cent (29/50) had difficulty putting on trousers and shoes.

Regression of cysts and sclerosis occurred in 46 per cent (23/50) of the hips in this series. Comparable results have been reported by Adam & Spence (1958), Duthie & Ellis (1963), Gudmundsson (1970), Harris & Kirwan (1964), Hirsch et al (1972), Morsink (1971), Olsson et al (1975) and Salenius et al (1971), whereas the majority of arthroscopically treated non-operatively show progression of cysts and sclerosis (Danielsson 1964). Joint space as measured at the latest follow-up was increased to a degree which was statistically significant. This seems to support the hypothesis of Nissen (1971) and Bjers (1974) that cartilage regenerates after osteotomy.

Table 6 Ability to put on socks and shoes

	Present Series No of hips	%	Olsson (1974) %	Danielsson (1964) %
In need of help or can manage with difficulty	29	58	60	70
Manages easily	21	42	40	30
Total	50	100	100	100

Table 8 Changes in cysts and sclerosis

	Femoral head		Acetabulum		Femoral head and acetabulum	
	No of hips	%	No of hips	%	No of hips	%
Regression	29	58	25	50	23	46
Unchanged	10	20	18	36	9	18
Progression	11	22	7	14	7	14
Behaviour different in femoral head and acetabulum					11	22
Total	50	100	50	100	50	100

Table 9 Pain relief related to changes in cysts and sclerosis in the femoral head

		Pain at rest No of hips			Weight bearing pain No of hips		
		No pain	Less pain	Unchanged or worse	No pain	Less pain	Unchanged or worse
by ages	Regression	24	2	3	15	10	4
	Unchanged	7	3	0	5	5	0
	Progression	6	2	3	0	8	3
Total		50			50		

Table 10 Pain relief related to changes in cysts and sclerosis in the acetabulum

		Pain at rest No of hips			Weight bearing pain No of hips		
		No pain	Less pain	Unchanged or worse	No pain	Less pain	Unchanged or worse
by ages	Regression	22	1	2	12	10	3
	Unchanged	11	5	2	8	8	2
	Progression	4	1	2	0	5	2
Total		50			50		

we find that intertrochanteric osteotomy is of long lasting benefit to the patients and with this knowledge we recommend that osteotomy be considered as a treatment for patients under 60 years of age. For those patients in whom osteotomy fails to give the expected pain relief, it can without undue difficulty be converted to a total hip replacement (Dupont & Charnley 1972).

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ACTURES OF THE P IN CHILDREN D ADOLESCENTS*

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... with K-
6 weeks,
without
adolescents
internal fixation may also be carried out with screws, in which case these must not cross an open epiphyseal plate. In both groups a non-weight-bearing period of 6 to 12 months is advisable.

The results in adolescents were definitely poorer than in children. Seemingly completely destroyed hips can reintegrate even to a nearly "restitutio ad integrum" state after a period of years.

Key words: avascular necrosis, children, femoral neck fractures, fracture treatment.

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Fracture of the femoral neck in children and adolescents is a rare injury. Only four papers concerning the long-term results of a large series have been published. The most comprehensive study is that of Rathliff (1974), who published the results of 170 fractures from 20 different orthopaedic clinics.

Recently Canale & Bourland (1977) have examined 24 patients originally examined by Ingram & Bachynski (1953) and have supplemented their report with an additional

36 cases. They compared their study with those of Rathliff (1968) and Lam (1971).

In these papers however no distinction has been made between fractures in children and in adolescents. Only Boitzy (1971, 1978) distinguishes in his cases between these age groups. In the present paper the long-term results in children and adolescents with hip fractures are examined.

PATIENTS AND METHODS

Fifty-two fractures of the proximal femur in 51 patients were examined during the period 1936 to

* This article is dedicated to Professor Dr A. N. in honor of his 65th birthday.

1974. The patients were divided into groups of children and adolescents. Children were defined as the age group from birth to the 11th year, while adolescents were defined as the age group from the 12th to the 17th year, inclusive.

Hip fractures in children were encountered in 10 boys and 16 girls. The average age at the time of the accident was 7 years (range 10 months to 11 years). The average follow-up period was 9 years (range 2 to 34 years). The series of adolescents consisted of 18 boys and 7 girls. The average age was 15.3 years (range 12 to 17 years). The average follow-up period was 14.8 years (range 7 to 28 years).

The fractures were classified as follows: Transsepiphyseal fractures, transcervical, basocervical and intertrochanteric fractures. The methods of treatment included non-operative treatment, immediate operative treatment and delayed operative treatment.

Treatment

Non-operative treatment included traction, immobilization in a hip-spica, bed rest until bony union and non-weight-bearing for 6 months. Immediate operative treatment consisted of open or closed reduction followed by fixation with K-wires, screws or nails. Fixation with K-wires was followed by a hip-spica for 4 to 6 weeks. Fixation with nails and screws made an external fixation unnecessary. A non-weight-bearing period of 6 months was recommended in all cases.

Operative treatment was considered delayed when performed later than 36 hours after the event.

In the analysis of the late results we have used the criteria described by Ratliff (1968). These are listed in Table 1.

RESULTS

Children

Transsepiphyseal fractures (Table 2 and Figure 1) were encountered in four patients with an average age of 5 years. Two children were treated operatively on the day of the accident with open reduction and K-fixation. At the follow-up, 7 and 12 years later, the results were classified as good. One child was treated non-operatively with traction. An avascular necrosis developed with shortening of the leg and limited motion. This result was classified as poor. The fourth child sustained an open fracture and was treated non-operatively with traction. Osteomyelitis developed, followed by avascular necrosis with destruction of the femoral head. An arthrodesis of the entire hip joint was eventually performed.

Transcervical fractures (Table 3 and Figure 2) were recorded in seven children with an average age of 8.7 years. Three children were treated operatively by internal fixation with K-wires on the day of the accident, and three were treated by delayed operation preceded by 2 to 3 weeks of traction and one child was treated non-operatively. In the three patients operated on immediately, one fair and two good results were encountered.

Among the three patients treated with delayed internal fixation, one fair and two poor results were found. The child treated non-

Table 1 Ratliff's classification of the results of treatment for fracture of the hip

	GOOD	FAIR	POOR
Pain	None or patient ignores it	Occasional	Disabling
Movement	Full or only terminal restriction	Greater than 50 per cent	Less than 50 per cent
Activity	Normal or patient avoids games	Normal or patient avoids games	Restricted
X-ray	Normal or some deformity of femoral neck	Severe deformity of femoral neck and mild avascular necrosis	Severe avascular necrosis degenerative arthritis arthrodesis

Table 2 Transphyseal fractures (children)

Case	Age at injury (years)	Treatment	Age at last follow-up	Vascular necrosis	Non-union	Irg length	Pain + limited motion	Premature closure	Coxa vara (Coxa valga)	End result
1	2	Open reduction + K-wires	9			+ 0.5 cm				Good
2	5	Open reduction + K-wires	17	-						Good
3	5	Traction and hip-sph. a for 7 weeks	12	yes		2 cm	yes	yes		Good
4	8	Traction and hip-sph. a for 12 weeks, then arch braces	16	yes		1 cm				Good

1974. The patients were divided into groups of children and adolescents. Children were defined as the age group from birth to the 11th year, while adolescents were defined as the age group from the 12th to the 17th year, inclusive.

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Children

Transsepiphyseal fractures (Table 2 and Figure 1) were encountered in four patients with an average age of 5 years. Two children were treated operatively on the day of accident with open reduction and K fixation. At the follow-up 7 and 12 years later, the results were classified as good. One child was treated non-operatively with traction. An avascular necrosis developed with shortening of the leg and limited motion. This result was classified as poor. The fourth child sustained an open fracture and was treated non-operatively with traction. Osteomyelitis developed, followed by avascular necrosis with destruction of the femoral head. An arthrodesis of the entire hip joint was eventually performed.

Transcervical fractures (Table 3 and Figure 2) were recorded in seven children with average age 8.7 years. Three children were treated operatively by internal fixation with K-wires on the day of the accident, and three were treated by delayed fixation preceded by 2 to 3 weeks of traction. One child was treated non-operatively with traction. Three patients operated on immediately had a fair and two good results were encountered.

Among the three patients treated with delayed internal fixation one fair and two poor results were found. The child treated

Table 1 Ratliff's classification of the results of treatment for fracture of the hip

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Activity	Normal or patient avoids games	Normal or patient avoids games	Restricted
X-ray	Normal or some deformity of femoral neck	Severe deformity of femoral neck and mild avascular necrosis	Severe avascular necrosis, degenerative arthritis, arthrodesis

Table 3 Transcervical fractures (children)

Case	Age at injury (years)	Treatment	Age at last follow-up	Avascular necrosis	Non-union	Leg length	Pain + limited motion	Premature closure	Second operation	Coxa vara Coxa valga	End-result
1	7	Open reduction + K-wires, day of injury	14	—	—	+1 cm	—	—	—	—	Good
2	10	Open reduction + K-wires	13	—	—	-1 cm	—	yes	Refracture after removal of K-wires 10 months postop, then traction for 12 weeks	—	Fair
3	7	Open reduction + K-wires, day of injury	16	—	—	—	—	—	—	—	Good
4	11	2 weeks' traction, then open reduction + K-wires	18	yes	—	-1 cm	yes	yes	—	Coxa valga 138°	Poor
5	9	3 weeks' traction then open reduction + K-wires	12	—	—	-1.5 cm	(+)	yes	—	—	Fair
6	9	Nailing 2 weeks post accident	20	yes	—	-2 cm	yes	yes	—	—	Poor
7	8	8 weeks' traction + hip-spica	15	—	yes	-1 cm	—	yes	Bone graft + K-wires 6 months post injury	Coxa valga 140°	Fair



Figure 2 A Transcervical fracture of the right hip of a 9-year old girl

B Open reduction and fixation with K-wires

treated operatively one good and one fair result were recorded, the one patient with a lateral fracture was classified as having a poor result. In this patient a valgus and derotation osteotomy had to be performed 2 years after the accident. With the exception of one patient, differences in the leg length occurred in all the cases, ranging from 0.5 to 2 cm. Four of the seven patients with intertrochanteric fractures developed a coxa valga.

Adolescents

Transcervical fractures (Table 6) were encountered in eight patients with an average age of 15 years. The follow-up was carried out an average of 14.3 years (range 7 to 28 years) after the accident. Three patients were treated non-operatively, another three were

treated by immediate internal fixation, whereas two patients were treated operatively after unsuccessful attempts at non-operative treatment for 1 to 3 months. Among the four patients treated by immediate operation one good and one fair result were achieved. In two patients treated operatively 1 or 2 months after the accident both had poor results. Two of the patients treated non-operatively developed non union. In one case bone grafting and simultaneous nail fixation was performed 2 years after the accident. In the other case a subtrochanteric valgus osteotomy and a bone graft were performed 10 months after the accident. Both fractures eventually healed. The third non-operatively treated patient had to undergo an arthrodesis of the femoral head (Figure 4). At the time of the follow-up examination six of the eight patients were



Result after 3 years

transcervical fractures had a leg-length discrepancy of 1 to 4 cm and one of these six patients also had a coxa valga. This was due to premature closure of the epiphysis in all cases.

Intertrochanteric fractures (Table 7) were recorded in 14 adolescent patients with an average age of 15.1 years. The average follow-up time was 13.4 years (range 9 to 26 years). Five patients were treated by immediate operation. Four patients were treated operatively 2 weeks to 3 months after accident and five patients were treated non-operatively with traction and plaster of Paris.

Among the five patients operated on immediately, three good, one fair and one poor result were encountered. The patient with a poor result sustained a postoperative osteitis, due to numerous operations with bone drilling. Among the patients treated with

delayed operation one good and three poor results were recorded. In this group one arthrodesis was planned at the time of re-examination. Among the non-operatively treated patients one good and four poor results were recorded, including one arthrodesis performed 9 years after the accident. In seven patients there was a leg-length discrepancy of 2 to 6 cm. One patient developed a coxa valga, another a coxa vara.

Intertrochanteric fractures (Table 8) were recorded in three patients with an average age of 17 years and an average follow-up time of 20 years (range 15 to 24 years). One patient underwent immediate operative treatment with a good result. One patient was treated operatively 4 weeks after the accident but had to undergo an arthrodesis 2 years later. The third patient was treated operatively 11 months after the accident and obtained a good result. Leg shortening of 2 cm was encountered in two patients.

Premature epiphyseal closure occurred in 30.5 per cent (9/26) of the children, predominantly following transcervical fractures (5/7). In adolescents premature closure occurred in 36 per cent (9/22) also predominantly after transcervical fractures (6/8). There was no correlation between epiphyseal closure and the method of treatment.

DISCUSSION

The analysis of our results revealed a marked difference between fractures of the femoral neck in children and those in adolescents, concerning both the prognosis and the treatment of choice. A clear distinction between children and adolescents should thus be drawn when dealing with femoral neck fractures. The prognosis is always better in children than in adolescents.

The treatment of choice in our series of children was immediate open reduction and internal fixation with K-wires, followed by immobilization in a hip-spica for 11 weeks. A



Figure 2 A Transcervical fracture of the right hip of a 9 year old girl



B Open reduction and fixation with K-wires

treated operatively one good and one fair result were recorded, the one patient with a lateral fracture was classified as having a poor result. In this patient a valgus and derotation osteotomy had to be performed 2 years after the accident. With the exception of one patient differences in the leg length occurred in all the cases ranging from 0.5 to 2 cm. Four of the seven patients with intertrochanteric fractures developed a coxa valga.

Adolescents

Transcervical fractures (Table 6) were encountered in eight patients with an average age of 15 years. The follow up was carried out an average of 14.3 years (range 7 to 28 years) after the accident. Three patients were treated non-operatively, another three were

treated by immediate internal fixation, whereas two patients were treated operatively after unsuccessful attempts at non-operative treatment for 1 to 3 months. Among the four patients treated by immediate operation, two good and one fair result were achieved, two patients treated operatively 1 to 3 months after the accident both had poor results. Two of the patients treated non-operatively developed non union. In one case bone grafting and simultaneous nail fixation were performed 2 years after the accident. In the other case a subtrochanteric valgus osteotomy and a bone graft were performed 10 years after the accident. Both fractures eventually healed. The third non-operatively treated patient had to undergo an arthrodesis due to complete avascular necrosis of the femoral head (Figure 4). At the time of the follow-up examination six of the eight patients were



Fig. 3. A. Basocervical fracture of the left hip of 7-year-old girl.



B After 3 months of conservative treatment no signs of bony union, signs of incipient avascular necrosis of the femoral head



P view of the hip after bone grafting operation.



D. Mushroom deformity of the hip joint, with a leg shortening of 3 cm, 12 years after the accident.



Figure 4 A Basocervical fracture of the left hip in a 16 year-old boy



B One year after the accident the fracture is healed. Signs of incipient capital necrosis



C Complete necrosis of the femoral head with comprehensive destruction of the hip joint 9 years after the accident



D Hip arthrodesis performed with a J-f nail

Table 5 *Intertrochanteric fractures (children)*

Case	Age at injury (years)	Treatment	Age at last follow-up	Avascular necrosis	Non-union	Leg length	Pain + limited motion	Premature closure	Coxa vara	Second operation	End-result
1	5/12	Open reduction + K-wires	16	—	—	-1 cm	—	—	Coxa valga 165°	—	Fair
2	11	Closed reduction + K-wires, day of accident	14	—	—	-0.5 cm	—	yes	—	—	Good
3	3	Bilateral fractures (flanged nails, 11 days after injury)	13	—	—	left leg +1 cm	yes	—	Coxa valga left 145° right 138°	Bilateral valgus and derotation osteotomy 2 years post injury	Poor
4	10	Spica cast	8	—	—	+0.5 cm	—	—	Coxa valga 142°	—	Fair
5	4	Hip-spica	7	—	—	+0.5 cm	—	—	Coxa valga 145°	—	Good
6	5	Hip-spica	18	—	—	—	—	—	—	—	Good
7	11	Traction and hip-spica for 7 weeks	23	—	—	-2 cm	(+)	yes	—	—	Fair

Table 6 Transcervical fractures (adolescents)

No.	Treatment	Age at last follow-up	Avascular necrosis	Non-union	Premature closure	Leg length	Pain + limited motion	Coxa vara Coxa valga	Second operation	End-result
	Open reduction 4 K-wires, day of injury	26	—	—	—	—	—	—	—	Good
2	13 Open reduction	26	—	—	yes	-1 cm	—	Coxa valga 140°	—	Fair
3	17 Open reduction + nailing day of injury	25	—	—	—	—	—	—	—	Good
4	15 Closed reduction (traction)	43	—	yes	yes	-3 cm	yes	—	Nailing and grafting of pseudarthrosis 2 years post injury	Poor
	5. Closed reduction + traction + spica cast)	30	—	yes	yes	-4 cm	yes	—	10 months post injury grafting and subtroc valgus osteotomy	Poor
	15 Closed reduction (spica cast)	22	yes	—	yes	-3 cm	—	—	Arthrodesis 1 year post injury	Poor
7	16 Open reduction + nailing 1 month	25	yes	—	yes	-4 cm	yes	—	—	Poor
8	16 Open reduction + nailing 3 months post injury	37	—	—	yes	-3.5 cm	yes	—	—	Poor

months' period of non-weight-bearing is recommended. In adolescents a three-
ed nail or screws is recommended
ad of K-wires and postoperative im-
lization is not considered necessary with
a stable internal fixation. However, 6
ths' non-weight-bearing is still considered
sable. Our results clearly demonstrate
all fractures of this type should be
ed by open reduction and internal
ion, with the exception of the impacted
action fractures.

femoral neck fractures among children
found that of the 13 cases treated by
ediate operation, 11 good and two fair
its were recorded. In four cases treated
elayed operation only one fair and three
results were encountered. Among the
ures treated non-operatively two good,
fair and three poor results were recorded.
ur opinion, there is thus no doubt that
results are improved by immediate
ative treatment.

mong adolescents with femoral neck
ures nine were operated on immediately,
within 36 hours after the accident. Six
i, two fair and one poor result were
rded at the follow-up. In the group with
yed operative treatment one good and
n poor results were recorded, while
ng the eight non-operatively treated cases
good and seven poor results were
red. This demonstrated that even in the
ip of adolescents the best results were
ined with immediate operative treatment.
the group of transepiphyseal fractures,
ch occurred only in four children, two
e treated operatively on the day of the
dent and two were treated conservatively.
ber (1978) stated that epiphyseal plates can
reely crossed with K-wires without any risk
damage. The K-wire fixation led to good
its without premature closure of the
physis. In the two non-operatively treated
tures a poor result was encountered.
n the group of 26 children only one non-
was encountered and this was in a
marily non-operatively treated trans-
vical fracture of the neck of the

femur. Among the 25 adolescents we found
four cases of non-union, following two
transcervical and two basocervical fractures.
The treatment had been non-operative in
three cases whereas one fracture was nailed
immediately. In our opinion immediate
operative treatment reduces the risk of non-
union.

Of the children, 30 per cent (9/27) had
premature closure of the epiphysis of the
femoral head. This occurred after one
transepiphyseal, five transcervical, one
basocervical and five intertrochanteric
fractures. Of the adolescents 36 per cent
(9/25) had premature closure after three
basocervical fractures and six transcervical
fractures. There was no significant correlation
to the mode of treatment.

We believe that damage to the epiphysis is
correlated with the extent of the damage to
the arterial supply of the femoral head at the
time of fracture. This conclusion seems to be
logical considering that blood supply to
the epiphysis is more likely to be disturbed in
transcervical fractures than in basal frac-
tures (Trueta 1957 and Chung 1976). This again
confirms our opinion that the fate of the
fracture is largely determined at the moment
of the accident by the amount of initial
damage to the blood supply. Additional
damage to the vascular system is caused by
repeated closed manipulations or by a too
extensive dissection of the joint area during
open reduction.

According to Canale & Bourland (1977) un-
displaced fractures of the neck of the femur
give better results than displaced fractures.
We believe that the reason for this is that
there is less vascular damage in undisplaced
fractures. Müller & Ganz (1974) stated that in
intracapsular fractures a puncture of the hip
joint should be performed as soon as possible,
with removal of the intracapsular hematoma.
This might prevent the vessels of the
proximal femur from being blocked by the
increased intracapsular pressure. We feel
this to be even more necessary in undisplaced
fractures as the joint capsule is undamaged. If
the puncture is not performed in patients

Table 7 Basocranial fractures (adolescents)

Case	Age at injury (years)	Treatment	Age at last follow-up	Avascular necrosis	Non-union	Premature closure	Leg length	Pain + limited motion	Coxa vara Coxa valga	Second operation	End-result
1	14	Open reduction, 4 K-wires, day of injury	24	—	—	—	—	—	Coxa valga 138°	—	Fair
2	12	Open reduction + K-wires, day of injury	29	—	—	—	—	—	—	—	Good
3	12	Open reduction + 4 K-wires, day of injury	22	—	—	—	-1 cm	—	—	—	Good
4	17	Open reduction + nailing, day after injury	26	yes	yes	—	-6 cm	yes	—	Postop osteitis several reop with nailing and grafting	Poor
5	16	Open reduction + nailing, 2 weeks post injury	42	yes	—	yes	-2 cm	yes	—	—	Poor
6	15	Open reduction + nailing, 4 weeks post injury	26	—	—	—	—	—	—	—	Good
7	14	Open reduction + nailing, 3 months post injury	29	—	—	yes	-2 cm	yes	—	—	Poor

Table 8 *Intertrochanteric fractures (adolescents)*

Case	Age at injury (years)	Treatment	Age at last follow-up	Avascular necrosis	Non-union	Premature closure	Leg length	Pain + limited motion	Coxa vara Coxa valga	Second operation	End-result
1	18	Open reduction and nailing, day of injury	33	—	—	—	—	—	—	—	Good
2	17	Open reduction and nailing, 4 weeks post injury	39	yes	—	—	-2 cm	yes	—	Arthrodesis 2 years post injury	Poor
3	15	Open reduction and nailing, 6 months post injury	39	—	—	—	-2 cm	(+)	—	—	Good

d non-operatively there may be very serious consequences

In young children we found avascular necrosis of the femoral head in 19 per cent. The necrosis followed one basocervical and two transcervical fractures and two epiphyseal fractures. Three patients were treated operatively after some weeks of conservative treatment and two patients were treated non-operatively. One patient developed an osteitis. Avascular necrosis never occurred in patients treated by immediate fixation.

In young adolescents avascular necrosis occurred in 30 per cent (9/25). There was no difference between the type of fracture and avascular necrosis in this group. The number of cases in our study is too small to allow definite conclusions to be drawn. It is our opinion however that immediate operative treatment gives better results than delayed operative treatment and non-operative treatment. This is in accordance with the results of Rathff (1964) and Lam (1971) and the results of Canale & Wood (1977).

The recommendation of K wires instead of screws for internal fixation of femoral neck fractures in children is based on the fact that screws apply traction to the epiphyseal

This nearly always leads to an epiphyseal dysplasia, as reported by Sussenbach & Jørgensen (1970). In adolescent cases where a premature closure of the proximal epiphyseal plate of the femur will not lead to significant shortening screws or three-flanged nails are recommended for internal fixation, because they produce a more stable fixation.

In conclusion we would like to suggest the following policy of treatment

Fractures of the neck of the femur in children and in adolescents should always be treated as an emergency and operative treatment should be undertaken as soon as possible.

When immediate operative treatment is not possible for whatever reason a puncture of the hip joint should be performed in intra-articular fractures.

Independent of the type of fracture internal fixation is always advisable. Screws and nails should not cross an open epiphyseal plate of the head of the femur. Crossing with K wires is less dangerous. In basal and transepiphyseal fractures a non-weight bearing period of 6 months is recommended.

In transcervical fractures a non weight bearing period of up to 12 months is regarded as necessary.

It is further concluded that the late results of fractures of the neck of femur are poorer in adolescent patients than in children and also that in all types of fractures, in children as well as in adolescents the risk of avascular necrosis, premature closure of the epiphysis and non union is less following immediate operative treatment, than following delayed operative treatment or conservative treatment.

The prognosis of these fractures depends on the amount of damage to the vascularization and consequently is determined by the localization of the fracture. Transcervical fractures are in this respect the most serious type.

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TERMINATION OF THE VITALITY OF THE FEMORAL HEAD WITH ^{99m}Tc -SN-PYROPHOSPHATE SCINTIGRAPHY

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A series of 14 patients who for various reasons were scheduled for total hip replacement were investigated ^{99m}Tc -Sn pyrophosphate scintigraphy and tetracycline labelling of the bone structure was performed prior to surgery, and subsequently the femoral heads were submitted to histological evaluation on decalcified as well as non-decalcified slides. The evaluation of the scintigraphs was performed by a specialist in nuclear medicine and the histological slides were evaluated by a pathologist, in both cases without

From this study it can be concluded that ^{99m}Tc -Sn-pyrophosphate scintigraphy is an excellent method of assessing bone vitality in the femoral head

Key words bone vitality femoral head scintigraphy, ^{99m}Tc -Sn pyrophosphate

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many years orthopaedic surgeons have searching for a simple, safe, accurate, reliable clinical test to assess the vascular supply of the femoral head. This would be a useful diagnostic and prognostic test to aid in planning treatment for several ailments.

Bramanian & McAfee (1971) introduced ^{99m}Tc -Sn-polyphosphate as a bone-seeking tracer. By a microautoradiographic technique Hoff (1978) showed that the tracer accumulated in mineralizing bone tissue, and suggested that the uptake of the isotope was related to the formation of the hydroxy apatite crystal. As the polyphosphate in the presence of alkaline phosphatase is readily hydrolysed

to pyrophosphate, Bowen & Garnett (1974) suggested that ^{99m}Tc -Sn pyrophosphate is the stable unit which deposits in the bone.

As the formation of bone is dependent on the vascular supply it seems reasonable to assume that a scintigraphic examination of the femoral head with ^{99m}Tc -Sn-pyrophosphate would reveal areas where the formation of new bone had ceased and bone necrosis had taken place due to a deficient vascular supply.

The aim of this work is to evaluate the reliability of ^{99m}Tc -Sn-pyrophosphate scintigraphic examinations for the determination of bone vitality in the human femoral head.

PATIENTS AND METHODS

Fourteen patients scheduled for total hip replacement were included in the investigation. Thus 14 femoral heads from 14 patients were studied. The indications for replacement of the femoral head are listed in Table 1.

Patient no. 1 had bilateral osteoarthritis of the hips and a replacement of the right hip had been performed a few months prior to the present investigation. *Patients nos. 2, 3 and 4* had unilateral osteoarthritis.

In 1962, at the age of 63 years, *patient no. 5* had been successfully treated with a Smith-Petersen nail for a medial femoral neck fracture on the left side. Eight years later a medial femoral neck fracture on the right side was treated with a Moore prosthesis. In 1978 X-ray examination of the left hip showed osteoarthritis and outward migration of the nail.

Patient no. 6 had rheumatoid arthritis. In 1971 a medial femoral neck fracture on the left side was successfully treated with Moore pins. Five years later she developed pain in the left hip, and X-ray examination in 1977 showed an osteoarthritis.

Medial femoral neck fractures in *patients nos. 7, 8, 9, 10, 11 and 13* were all initially treated with closed reduction and osteosynthesis with three to four A-O (ASIF) 6.5 mm lag screws. Three of the fractures united, but a secondary collapse of the femoral head developed. In two patients a varus displacement occurred, and one patient developed a pseudarthrosis.

In 1968 *patient no. 12* was treated with McLaughlin osteosynthesis for a medial femoral neck fracture. A year later the implant was removed because of pain which was related to the implant. In 1970 a pseudarthrosis developed and was treated with bone grafting without success.

In 1975 *patient no. 14* had a renal transplant on the left side, but the graft was removed a few weeks because of infection. From the beginning of 1977 the patient complained of pain in the left groin. A radiologically visible collapse of the left femoral head was diagnosed in October 1977.

At the same time as the clinical and radiological investigations of the patients were carried out a $^{99m}\text{Tc-Sn-pyrophosphate}$ scintigraphic investigation was performed.

Two hours prior to the scintigraphic investigation each patient received 10 mCi $^{99m}\text{Tc-pyrophosphate}$ intravenously (3-15 mCi $^{99m}\text{Tc-pyrophosphate}$). An anterior image of both hips was obtained.

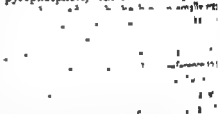


Figure 1) on the affected side was compared with the uptake in the opposite normal hip (or in *patients nos. 1 and 5* with the uptake in the unaffected side).

Table 1 The age and sex of the patients, and the duration of the disease

Pt. no.	Sex	Age in years	Pathological picture	Duration
1	♂	72	Osteoarthritis coxae sin.	5 yrs
2	♀	63	— — —	5 —
3	♀	78	— — —	3 —
4	♀	66	— — —	2 —
5	♀	79	Osteoarthritis seq. fractura collis femoris medialis	15 —
6	♀	68	— — —	5 —
7	♀	71	Collapsus capitis femoris seq. fractura collis femoris med.	17 mos
8	♀	66	— — —	15 —
9	♀	73	— — —	9 —
10	♀	62	Fractura collis femoris medialis — failure of implant	3 —
11	♂	78	— — —	2 —
12	♂	78	Pseudarthrosis collis femoris, seq. fract. collis fem. med.	8 yrs
13	♀	91	— — —	14 mos
14	♂	40	Collapsus capitis femoris, secondary to renal transplant ?	2 yrs

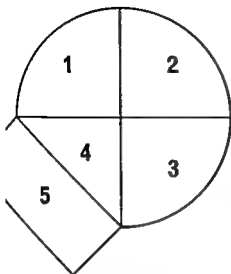


Fig. 1 The accumulation of isotopes was noted in the four quadrants of the femoral head and in the femoral neck

RESULTS

The scintigraphs of the osteoarthrotic hips showed an increased activity, either distributed diffusely all over the femoral head (pts nos 2, 5 and 6) or predominantly in the two upper quadrants (pts nos. 1, 3 and 4) (Figures 2 to 5). When a prosthesis was present (pts nos 1 and 5) no activity was found in the area of the femoral head (Figure 6).

In the case of collapse of the femoral head following a medial femoral neck fracture demonstrated radiologically (pts nos 7, 8 and 9) (Figure 7) decreased activity or no activity was found in the femoral head, whereas increased activity was seen in the femoral neck (Figure 8). In the two patients where failure of an implant led to hip replacements the activity found in the femoral head was normal in one (pt no 10) and decreased in one (pt no 11), but in both patients the femoral neck activity was increased.

When a pseudarthrosis was present (pts. nos 12 and 13) (Figures 9 and 10) the scintigraphs showed an absence of activity corresponding to the femoral head, even though the X-ray examination showed no collapse of the femoral head.

In patient no 14 the scintigraphs showed less activity in the upper lateral quadrant of the femoral head compared with the high level of activity in the remaining three quadrants (Figures 11 and 12).

No discrepancies were found between the findings of the two histological evaluations of bone vitality in the femoral head. When tetracycline was present, the decalcified slides showed the presence of osteocytes and new bone formation. Lack of tetracycline was tantamount to bone necrosis, with no osteocytes, no bone formation and necrosis of the soft tissue.

When the scintigraphic examination showed no activity or a decreased amount of activity the histological examination showed bone necrosis, whereas increased activity corresponded to vital bone. The overall results of the study are shown in Table 2.

on the same side) and graded "0" for no activity, "1" for less than normal uptake, "2" for normal uptake and "3" for greater than normal uptake (Table 2).

In all but one patient (no 14) a tetracycline ring was carried out on the 15th, 14th, 3rd and 2nd preoperative day using oxytetracycline given orally four times a day.

The femoral head was divided into two and one was decalcified with either Calcefix (Kunz Instru-

A/S Denmark) or EDTA (E. Merck, Darmstadt, Germany). Histological slides were stained with haematoxylin-eosin and examined by a pathologist without reference to clinical history or X-ray pictures. Loss of osteocytes and necrosis of the soft tissue between trabeculae were indications of a deficient blood supply. It was noted whether new bone formation was present or not.

The other halves of the femoral heads were embedded in methyl methacrylate. In eight specimens thin sections were cut from the embedded block and then ground to a thickness of about 100 μ m. From the remaining six specimens 100 μ m thick sections were cut directly from the block utilizing a Leitz Sagemikrotom (Leitz, Wetzlar, Germany). The sections were examined in ultraviolet light and evaluated for the presence of tetracycline by reference to the fluorescent state.



Figure 2 X ray picture of a 79 year old patient showing secondary osteoarthritis of the left hip following a medial neck fracture (pt no 5)

Figure 3 $^{99}\text{Tc-Sn}$ pyrophosphate distribution in the hip (pt no 5) Increased uptake is seen in all four quadrants of the femoral head.



Figure 4 X ray picture of a primary osteoarthritis in the right hip (pt no 3)

Figure 5 The distribution of $^{99}\text{Tc-Sn}$ pyrophosphate in a patient with primary osteoarthritis (pt no 3) The increased uptake is located in the two upper quadrants of the femoral head.



DISCUSSION

The ability of $^{99m}\text{Tc-Sn}$ phosphate compounds to deposit in bone as demonstrated by Subramanian & McAfee (1971) (polyphosphate) and Perez et al (1972) (pyrophosphate) has led to the study of a variety of bone disorders, as listed by Silberstein (1976). It has been shown by Tilden et al (1973), Galasko (1975) and Grciff (1978) that $^{99m}\text{Tc-Sn}$ polyphosphate/pyrophosphate accumulates in newly formed mineralizing bone tissue. The interpretation of the scintigraphs obtained in this study is based on this view.

In the femoral heads showing increased uptake, i.e. primary and secondary arthrosis, one has to look for a trigger mechanism inducing new bone formation. According to Wolff's Law (1890) an altered stress pattern should induce a remodelling with increased uptake of isotope compounds. Lane et al. (1977) found that the vascularity and remodelling in the subchondral calcified zone varies according to stresses within the joint, possibly by stress induced microfractures as suggested by Radin et al. (1973). The

Fig. 6 $^{99m}\text{Tc-Sn}$ -pyrophosphate distribution in the hip of pt no 5, who had a Moore prosthesis inserted 8 years prior to the present investigation. No uptake of the isotope is seen at the prosthesis.

Table 2 The results of the scintigraphic and histological evaluation

Scintigraphic evaluation area					Histological evaluation					
1	2	3	4	5	V	O	B	N	T	
3	2-3	3	2	2-3	+	+	+	-	+	
3	3	2-3	2	2	+	+	+	-	+	
2-3	2-3	2	2	2	+	+	+	-	+	
3	2-3	2	2-3	2	+	+	+	-	+	
3	3	3	3	2	+	+	+	-	+	
3	3	3	3	2	+	+	+	-	+	
0	0	0	3	2-3	-	-	-	+	-	
0	0	0	0	3	-	-	-	+	-	
2-3	1	1	3	2	-	+	-	+	-	
2	2	3	3	3	+	+	+	-	+	
0	0	0	0	2-3	-	-	-	+	-	
0	0	0-1	0	2	-	-	-	+	-	
1	1	1	1	2-3	-	-	-	F	-	
0	1	3	3	2	+-	±	+	±	0	

vital femoral head, O = osteocytes, B = new bone formation, N = necrosis of the intratrabeular tissue, T = tetracycline and F = fatty degeneration of the intratrabeular tissue.



Figure 2 X ray picture of a 79-year-old patient showing secondary osteoarthritis of the left hip following a medial neck fracture (pt no 5)

Figure 3 $^{99}\text{Tc-Sn}$ pyrophosphate of the hip (pt no 5) Increased uptake in all four quadrants of the femoral head.



Figure 4 X ray picture of a primary osteoarthritis in the right hip (pt no 3)

Figure 5 The distribution of pyrophosphate in a patient with osteoarthritis (pt no 3) The uptake is located in the two upper quadrants of the femoral head.



Figure 11 X ray picture (tomography) of a patient with a partial femoral head necrosis following a kidney transplant (pt no 14)



Figure 12 ^{99m}Tc Sn pyrophosphate distribution in a patient with a partial femoral head necrosis following a kidney transplant (pt no 14). Increased activity is seen in quadrants 2, 3 and 4 and decreased isotope accumulation is seen in quadrant 1.

scintigraphs of coxarthrosis in this study compare very well with the findings of Nielson et al (1965) who performed scintigraphy after intravenous injection of ^{45}Ca and the findings of Heerfordt et al (1976) who employed F^{18} in their studies.

When a radiologically visible collapse is indicated the presence of femoral head necrosis, the scintigraphs showed decreased uptake. The fractures had united and the collapse developed during weight bearing. The collapse appears to be the result of multiple microfractures in the subchondral zone where repair can take place due to an impaired blood supply. As the trabeculae supporting the cartilage deteriorate the cartilage becomes loose and can be removed like the peel of an orange. With continued weight bearing the cartilage is pressed further and further down on the remains of the femoral head until it rests on vital bone.

Shoji et al (1972) examined femoral neck fractures by Sr^{90} scintimetry. They found an

increased mean head count rate up to 4 years after the fracture in patients with osteonecrosis. As these authors dealt mainly with the late repair process after avascularity and collapse of the femoral head, no contradiction exists between their findings and the findings of McGrail et al (1974), Riggins et al (1974), D'Ambrosia et al (1975a) and Stadalnik et al (1975) who in studies of medial femoral neck fractures using F^{18} scintigraphs could diagnose the avascularity of the femoral heads by the lack of isotope accumulation in the area. The scintigraphs produced by D'Ambrosia et al (1975b) who used ^{99m}Tc -diphosphonate by Greiff et al (1980) who used ^{99m}Tc -Sn pyrophosphate and by Meyers et al (1977) who used ^{99m}Tc -sulphur-colloid all demonstrated clearly the vascular/avascular status of the femoral head following medial neck fractures.

In this study the scintigraph showed decreased or no uptake of the isotope in two

patients with medial femoral neck pseudarthrosis even though no radiological collapse of the femoral head was present. The histological diagnosis was necrosis in both cases. The pseudarthrosis had apparently in some way protected the femoral heads from a collapse, probably by pain which prevented the normal use of the leg and consequently there was insufficient loading for the production of microfractures. In patients where a failure of implants following medial femoral neck fracture indicates repeated surgery or where a medial femoral neck pseudarthrosis has developed, scintigraphy is the best method of evaluation and a prerequisite for selection of the proper surgical procedure (pts nos 10-13). Reosteosynthesis and bone grafting should probably not be done in patients with avascular femoral heads. These patients will be better off with a hip replacement.

In non-traumatic necrosis of the femoral head Cameron (1969) found an increased Sr^{85} activity over the femoral head, and tissue examination revealed this activity to be located in the repair reaction at the margin of the necrotic bone. This finding is compatible with the findings of the present study in patient no. 14 (Figure 12). The aetiology of this type of lesion is obscure, but believed to be related to high doses of steroid (Harris et al 1974), and fatty embolization in the subchondral area as suggested by Cruess (1977).

The study has shown $^{99\text{m}}\text{Tc}$ -Sn-phosphate scintigraphy to be an excellent method for assessing bone vitality in the femoral head. The convenient half-life of $^{99\text{m}}\text{Tc}$, the easy preparation of the kit and the results obtained in this study indicate that $^{99\text{m}}\text{Tc}$ -Sn-pyrophosphate scintigraphy could be an important tool in the diagnosis of a variety of bone disorders, permitting more accurate prognoses, and enabling the selection of the most appropriate surgical procedure and the most suitable preventative measures.

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LY DETECTION BY ^{99m}Tc-Sn-PYROPHOSPHATE NTIGRAPHY OF FEMORAL HEAD NECROSIS LOWING MEDIAL FEMORAL NECK FRACTURES

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A selected series of 24 patients with displaced medial femoral neck fracture, treated with closed reduction and osteosynthesis with cancellous bone screws (ASIF), were investigated.

During an observation period of 6 to 26 months, serial hip joint scintigraphies were performed and compared with serial X-ray examinations. At the first scintigraphic examination performed on average 5-6 weeks after the fracture, two separate investigators found a decreased amount of activity or no activity in the femoral head of 10 and 8 patients, respectively. At the second scintigraphic examination performed on average 11.1 weeks after the fracture both investigators found no activity or a decreased amount of activity in 8 patients. This figure declined to 7 during the following period, because one patient with decreased activity was recorded as having normal activity 15 months after the fracture. These 7 patients all developed radiological signs of femoral head collapse on average 16.3 months after the fracture (range 5-26 months), whereas their scintigrams displayed decreased or absent tracer uptake on average 1.2 months after the fracture ($P < 0.01$). None of the patients with initially normal or increased uptake later showed decreased or absent uptake during the study and none developed radiological collapse.

It may be concluded that absent or decreased uptake of ^{99m}Tc-Sn-pyrophosphate in the femoral head following medial femoral neck fracture indicates femoral head necrosis and a high risk of late segmental collapse, whereas normal or increased uptake implying preserved blood supply means that late segmental collapse will probably never develop.

Key words: bone vitality, femoral head collapse, femoral head necrosis, medial femoral neck fracture, scintigraphy, ^{99m}Tc-Sn pyrophosphate

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al femoral neck fractures have a high
lence of late segmental collapse of the
femoral head. A variety of methods have been
tested for predicting the viability of the
femoral head, but none have hitherto been
ciently easy or rapid to perform or
ble enough for clinical application. Greiff
0) showed that ^{99m}Tc-Sn-pyrophosphate

scintigraphy is a reliable method for the pre-
diction of bone vitality of the femoral head.
In the present study this method was
employed in a selected series of intracapsular
medial neck fractures and the ability of the
method to diagnose femoral head necrosis
and to predict late segmental collapse was
evaluated.

NO OF PATIENTS

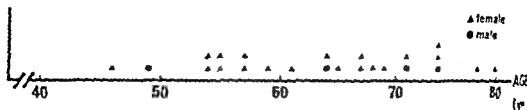


Figure 1 Sex and age distribution

PATIENTS AND METHODS

This study includes 24 patients with displaced medial femoral neck fractures who were treated with closed reduction on an extension table and osteosynthesis with three to four 6.5 mm cancellous bone screws (ASIF). The distribution as regards age and sex is given in Figure 1.

At regular intervals during the observation period, which ranged from 6 to 26 months (mean value 14 months) a $^{99m}\text{Tc-MDP}$ (Mallinckrodt) was administered intravenously.

After an intravenous injection of 10 mCi $^{99m}\text{Tc-MDP}$ and with the patient in the supine position, an anterior image of both hips was obtained utilizing a gamma camera (General Electric Radi camera II) supplied with a 6 mm pin hole collimator collecting a total of 250 000 counts.

For the evaluation of the scintigraphs the isotope accumulation in the four quadrants of the femoral head and neck (Figure 2) was compared

with that in the scintigraphs of the contralateral normal hip and graded 0 for no uptake, 1 for decreased uptake, 2 for normal uptake, and 3 for increased uptake. The scintigraphs were evaluated separately by two members of the staff of the Department of Clinical Physiology and reference to patient history and X-rays.

The scintigraphs were considered to be normal when a grading of at least 2 was encountered in all four quadrants, as showing a partial defect when a grading of 0 or 1 was found in one or two quadrants, and as showing a total defect when a grading of 0 or 1 was encountered in three or more quadrants (Greiff 1980).

For the purpose of this study all the scintigraphs were reviewed by two radiologists. The findings relating to the femoral head were graded for normal findings, S for slightly irregularity of the femoral head or for areas of osteosclerosis and C for collapse of the femoral head.

RESULTS

Scintigraphically identical gradings were obtained by the two examiners in 71 per cent of the 380 different areas. While a difference of one step on the 4-step scale was encountered in 21.9 per cent, differences of two and three steps were encountered in 2.6 per cent and 2.6 per cent.

In the group of patients with normal uptake on the scintigraphs (Table 1) minor discrepancies between the gradings of the two examiners occurred on the scintigraphs, as one examiner had a grading of 1 in one quadrant in two of the hips while the other examiner found a grading of 2. These discrepancies disappeared when the gradings of the second scintigraph were compared with the differences of the first.

Figure 2 Areas of interest

Table 1 Results of the $^{99m}\text{Tc-Sn}$ pyrophosphate scintigraphy (femoral head vitality and the radiological evaluation (radiologically visible collapse))

	S C I N T I G R A P H Y						RADIOLOGICAL COLLAPSE
	FIRST EXAM		SECOND EXAM		FOLLOW UP		
	A	B	A	B	A	B	
OTAL DEFECT	6	6	6	6	6	6	6
ARTIAL DEFECT	4	2	2	2	1	1	1
ORMAL OR IN- CREASED UPTAKE	14	16	16	16	17	17	0

Two examiners were of no significance, as discrepancies occurred in the overall evaluation of the scintigraphs.

Based on the scintigraphic findings of the two scintigraphs following the fracture, formed on average after 5.8 weeks and 6.5 weeks, the patients could be divided into three major groups, i.e. patients with normal uptake in the femoral head and patients with decreased or no uptake. The latter group could be divided into two subgroups according to the extent of the area of decreased uptake (Table 1).

In none of the sixteen patients showing normal uptake in the femoral head did the scintigraphic findings change to decreased uptake during the observation period, and none of these patients developed radiological signs of femoral head necrosis.

Six patients whose scintigraphs displayed decreased or no uptake of the isotope in three or four quadrants, an average of 4.6 weeks after the fracture (range 0.3–9.5 weeks) (Figures 3 and 4) all developed radiological



Figure 3 Normal $^{99m}\text{Tc-Sn}$ pyrophosphate hip scintigraphy (patient no 2, right side)



Figure 4 Pathological $^{99m}\text{Tc-Sn}$ pyrophosphate hip scintigraphy performed 5 months after the fracture showing defective isotope uptake in areas 1, 2 and 3, and increased uptake in areas 4 and 5 (patient no 2, left side)

gained wide acceptance, primarily because of technical complexities, difficulties in interpretation, high cost, or because surgical invasion is often required to perform the test.

With the introduction of the ^{99m}Tc -labelled phosphate compounds by Subramanian & McAfee (1971) (polyphosphate) and Perez et al (1972) (pyrophosphate) a new development in the solution of the problem appeared possible. These radionuclides accumulate wherever formation of new bone material takes place (Greiff 1978) rendering the skeletal system visible by scintigraphic technique. Hyperaccumulation is seen in regions of new bone formation, as for instance at fracture sites. A primary condition for new bone formation is preservation of the blood supply to the investigated area. In the case of avascular necrosis, tracer accumulation will not take place at all, thus making the necrotic spot visible as a defect devoid of tracer (except for the activity in the surrounding tissue) (Greiff 1980).

Korvald & Sundsfjord (1974) performed ^{99m}Tc -Sn-polyphosphate scintigraphy in 16 patients of whom 15 had proximal femoral fractures but no definite conclusion could be drawn as to the predictive ability of the method as regards late segmental collapse, probably because of the relatively small size of their material.

In a selected material of 40 patients with displaced medial neck fractures, treated with ternal pedicle flap and osteosynthesis, Meyers et al (1977) found 32 patients with necrosis of the femoral head before surgery, judged by ^{99m}Tc -sulphur-colloid scintigraphy, supplemented with histological examination of a core biopsy from the femoral head. Of the 40 hips, 25 which could be investigated 1 year or more after the fracture showed normal scintigraphy, and the rate of late segmental collapse fell to zero.

This method however, is not readily comparable to scintigraphy with ^{99m}Tc -pyrophosphate, since ^{99m}Tc -sulphur-colloid is taken up by the Kupffer cells in bone marrow and not by the bone material itself.

In our study decreased or no uptake in

three or four quadrants of the femora invariably led to a radiologically detectable segmental collapse. The accurate diagnosis of femoral head necrosis determined on average more than 1 year before the radiological signs developed. Only a minor defect of activity was found. The prediction was uncertain. A minor defect possibly caused by internal vascular changes in the femoral head due to the impaction led to either collapse or revascularization depending on the external vascular supply.

Even more important, increased normal activity on scintigrams in the first period following the fracture was indicated that no femoral head necrosis was present and that late segmental collapse would not develop.

As shown by Bohr & Larsen (1967) revascularization is accompanied by formation of new bone by creeping substitution, but this is a rather time-consuming procedure. Charnley et al (1957) showed only 0.5 cm of the area close to the fracture in the femoral head became revascularized within 4.5 months. In this study positive signs of revascularization with bone apposition were found as increased radioactivity in the area around the fracture and the lower medial quadrant but a complete revascularization was not achieved in a patient with a scintigraphic total defect before late segmental collapse developed even though weight-bearing in two crutches was deferred for approximately 1 year. Revascularization only occurs very slowly. It is pertinent to ask whether revascularization is worth waiting for. This necrosis of the femoral head is actually "Calvé-Legg-Perthes disease" of adults, and knowing that revascularization of a child's head in several years revascularization of an adult femoral head can be expected to take a longer

The early prediction of femoral head necrosis and subsequent segmental collapse shown in this study indicates that scintigraphy will become a valuable diagnostic tool in the management of femoral

MORAL NECK FRACTURES

Cases Treated by Multiple Percutaneous Pinning

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A prospective series of 165 displaced subcapital fractures of the femoral neck treated with reduction and percutaneous multiple pinning is presented. The method offers the advantages of a short operating time, no loss of blood, immediate weight-bearing and no infection problems. Furthermore the operative procedure can be performed under local anaesthesia.

In Garden stage 3 fractures union occurred in 97 per cent and late segmental collapse in 8 per cent. In Garden stage 4 fractures union occurred in 72 per cent and late segmental collapse in 14 per cent.

Failures were almost exclusively encountered in the group of poorly reduced fractures which had a failure rate of 77 per cent.

In the case of non-union 75 per cent of the patients needed a secondary hip replacement whereas only 16 per cent of the patients with late segmental collapse had received an arthroplasty at the time of the follow-up.

Keywords: femoral neck fractures, fracture fixation

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osseous revascularization of a partially totally avascular femoral head can take place (Brown & Abrams 1964, Catto 1965, Jørgensen et al. 1974, Meyers et al 1977 and Jørgensen & Lempert 1977). In order to obtain good results in the treatment of displaced femoral neck fractures exact fracture reduction and stable fixation is essential (Jørgensen 1961, 1971, Brown & Abrams 1964, Jørgensen 1966, Barnes et al 1976, Arnold et al 1974, Arnold & Lempert 1977 and Meyers et al 1977).

This study presents a series of 165 displaced subcapital fractures of the femoral neck treated by percutaneous multiple pinning.

PATIENTS AND METHODS

During the period January 1st to December 31st, 1975, a consecutive series of 165 patients over the

age of 50 with displaced subcapital fractures of the femoral neck were treated with reduction and percutaneous multiple pinning of their fracture.

The fractures were divided into groups according to Garden (1961) as demonstrated in Figure 1. In the present series 92 fractures belonged to stage 3 and 73 to stage 4.

Eighty-eight per cent (146/165) of the patients were operated on using spinal or epidural analgesia. If contraindications were encountered a local anaesthetic was injected into the hip joint, and into the skin, muscles and periosteum on the lateral aspect of the subtrochanteric femoral area. Local anaesthesia was used in 19 cases.

At operation the patient was placed supine on the fracture table. The fracture was reduced by gentle traction and inward rotation or by Leadbetter's method (Leadbetter 1933). The reduction was checked by means of a two-plane image intensifier. The appropriate length of the nail was determined by placing nails on the ventral aspect of the hip under image intensification. Through a skin incision 1-1½ cm long below the greater trochanter the first nail was inserted through the cortical bone. A further two nails were placed parallel to the first in the frontal view.



Figure 1 Classification of femoral neck fractures according to Garden (1961) A Stage 3. Complete subcapital fracture with partial displacement B Stage 4. Complete subcapital fracture with complete displacement

In the lateral view the nails can be placed parallel or crossed (Figure 2a). One nail must be supported by the calcar femorale. The nail must be directed at the correct angle before penetrating the cortical bone as later adjustment is difficult. The tips of the nails were placed in the subchondral bone preferably leaving only the screw-thread outside the cortical bone (Figure 2b). The required instrumentation is shown in Figure 3.

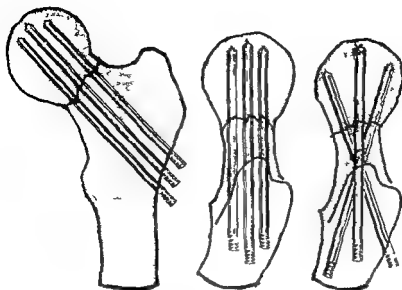
The patients were mobilized from the first postoperative day and allowed as much weight-bearing as they could tolerate. A clinical and radiological follow-up was undertaken every 6 months for 2-3 years after the internal fixation.

The follow-up was attended by 112 patients or 88 per cent, 49 had died and four were lost to follow-up. The average age of the patients who had died was 83 years (range 61-96 years). None of the deaths could be related to the femoral neck fracture.

The average follow-up period was 29 months (range 24-36 months). The series comprised 93 women and 19 men with an average age of 74 years (range 50-94 years).

In order to obtain a reproducible assessment of the patients' clinical results after treatment a classification of the prefracture condition is required. At the clinical follow-up the patients were assessed according to Andersson & Villberg (1972) as summarized in Table 1. This modification classified the patients into four stages. Stage 1 0-4 points, stage 2 5-7 points, stage 3 8-10 points and stage 4 11-21 points. Taking into consideration the patients' condition about their prefracture condition and function and using the contralateral limb as a control, mobility at follow-up the end result was assessed as excellent if the prefracture condition was good or if one stage below, good if two stages below and poor if a total hip replacement was indicated.

Radiologically the Garden alignment (1971) was used to describe the reduction of the fractures. Good reduction was defined as an angle of about 160 degrees (155-165 degrees) in the frontal view of the weight-bearing femur. In the lateral view the normal position of the trabeculae was used as a guide.



2A Ideal positions of pins Pins placed parallel in the frontal view with support on the calcar In the lateral view the pins may be placed parallel or crossed



2B Ideal positions of pins Pins placed with the tips in the subchondral bone leaving only the threads outside the cortical bone

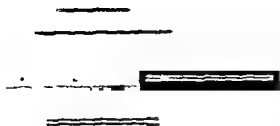


Figure 3 Instrumentation for percutaneous pinning. The shortest and longest pins are shown as well as the pin holder device

of the head relative to the neck was 180 degrees (155–185 degrees). Malreduction was encountered in fractures outside the limits 150/190 in the frontal or lateral view.

In united fractures any deformity in the contour of the weight-bearing surface of the femoral head not seen in the original X-rays was considered as a late segmental collapse. Fracture union occurs when the trabeculae grow over the entire fracture line. This is often difficult to judge, therefore union was considered established if no secondary dislocation had occurred within a period of 2 years.

RESULTS

The average hospitalization time was 22 days (range 3–65 days). The mortality within 1 month was 3 per cent (5/165), within 6 months 13 per cent (22/165) and within 2 years 29 per cent (49/165). None of the deaths could be related to the femoral neck fracture or its treatment.

In the case of nail loosening which never included all nails, the nail was removed under a local anaesthetic. No superficial or deep infections were encountered.

It was evaluated whether there was any difference between stage 3 and stage 4 fractures as regards the quality of fracture reduction (Table 2). Stage 3 fractures were significantly easier to reduce than stage 4 fractures.

The clinical assessment at follow-up was excellent results in 82 cases and good in 11, i.e., satisfactory results were recorded in 83

per cent (93/112) of the patients. The failure rate corresponding to the good (5 patients) and poor (14 patients) was 17 per cent (19/112) of the cases.

In order to judge whether the regrouping in Garden stages was of prognostic value the results in Garden 3 and 4 were compared. Table 3 demonstrates that uneventful healing was obtained in 56 per cent (56/63) of stage 3 fractures with 58 per cent (28/49) of those in stage 4.

To evaluate the relationship between radiologically good and poor fracture reduction as compared with the final results at follow-up, the case material was divided into two groups. Group 1 consisted of 86 successfully reduced fractures. Of these 86 per cent (84/86) healed and two non-unions. Seven per cent (6/34) of healed fractures developed late segmental collapse. Group 2 consisted of 26 poorly reduced fractures. Non-unions were encountered in 54 per cent (14/26) of these. Of the 12 fractures that healed, 43 per cent (6/12) developed late segmental collapse (Table 4). The difference between the two groups is highly significant. Well reduced fractures accounted for a failure rate of 17 per cent (8/86) whereas the group of poorly reduced fractures had a 77 per cent failure rate.

In order to find out whether anything other than poor reduction, according to Garden, could account for the poor results in group 2, the X-rays were reviewed. Special attention was given to other factors than malreduction. *Ad latus* displacement and sufficient bone contact between the fracture components were shown in Figure 4. These factors were encountered in 20 cases (Table 5). It was found that the remaining six fractures were united uneventfully without any late segmental collapse or femoral head ischaemia, though reduced with an average of 10° backward angulation. In the six cases there was firm contact between the fracture ends of the fracture over the whole fracture line and no *ad latus* displacement.

At the follow-up 14 patients were c-

Table 1 Assessment system according to Andersson & Moller Nielsen (1972)

un	1 Pain on starting to walk	no 0, yes 1
	2 Pain when walking	no 0, only on strain 1, on all walking 2
	3 Pain when resting	no 0, after strain 1, spontaneous 2
obility	1 Active flexion (straight leg raising)	0-45 degrees $\times 0.6$ (= max 27) 45-90 degrees $\times 0.4$ (= max 18) 90-150 degrees $\times 0.1$ (= max 6)
	2 Abduction	0-15 degrees $\times 0.6$ (= max 9) 15-30 degrees $\times 0.4$ (= max 6) 30-60 degrees $\times 0.1$ (= max 3)
	3 Adduction	$\times 0.2$
	4 Outward rotation	0-15 degrees $\times 0.3$ (= max 4.5) 15-30 degrees $\times 0.2$ (= max 3) 30-80 degrees $\times 0.1$ (= max 5)
	5 Inward rotation	$\times 0.2$
unction	1 Tension	no 0, yes 1
	2	
	3	
	4 Walking distance without pain	more than 1,500 metres 0, 400-1,500 metres 1, 100-400 metres 2, 1-100 metres 3, cannot walk without pain 4, cannot walk 5
	5 Can put on own shoes and stockings	yes 0, with difficulty 1, no 3
	6 Can manage stairs	yes 0, with difficulty 1, no 3
	7 Can sit on a low chair	yes 0, with difficulty 1, no 3
	8 Can take a bath without help	yes 0, with difficulty 1, no 3
	9 Working capacity	better than before +1, as before 0, worse than before 2

ASSESSMENT OF MARKS

	0	1	2	3	4	5	6	7
ity	0	1	2	3	4	5		
ion	70	69-50	49-35	34-20	19-10	9-0		
	0-1	2-3	4-5	6	7	8-9	10-11	12-13
	8	9	10	11				
ity								
ion	14-15	16-18	19-21	22-27				
	Good		Acceptable		Poor			
ity	0-1		2-3		4-5			
ion	0-1		2-3		4-5			
	5-13		4-7		8-11			
	0-4		5-10		11-21			

Table 2 Quality of reduction in stage 3 and stage 4 fractures (Garden 1961) Results of 165 patients

re stage	Good	Reduction Poor	Total
3	88 % (81/92)	12 % (11/92)	92
4	62 % (45/73)	38 % (28/73)	73
	76 (126/165)	24 % (39/165)	165

square test $P < 0.01$

Table 3 Results of radiological follow-up in the two fracture stages (Garden 1961)

	Stage 3	Stage 4	Total
Non union	3 % (2/63)	28 % (14/49)	14 % (16/112)
Late segmental collapse	8 % (5/63)	14 % (7/49)	11 % (12/112)
Total failure rate	11 % (7/63)	42 % (21/49)	25 % (28/112)

Chi square test $P < 0.001$

Table 4 Radiological results in relation to fracture reduction

	Reduction according to Garden (1971)		
	Good	Poor	Total
No. of fractures	86	26	112
Non union	2 % (2/86)	54 % (14/26)	14 % (16/112)
Late segmental collapse	7 % (6/86)	23 % (6/26)	11 % (12/112)
Total failure rate	9 % (8/86)	77 % (20/26)	25 % (28/112)

Chi square test $P < 0.001$

as having clinically poor results. Twelve had fractures with non-union and two had late segmental collapse. In order to evaluate which was the most serious complication, non-union or late segmental collapse, as regards the clinical result, all radiological cases of non-union and late segmental collapse were considered. Out of 16 fractures with non-union 75 per cent (12/16) needed an arthroplasty, whereas this procedure was only necessary in 16 per cent (2/12) of the cases with late segmental collapse.

DISCUSSION

So far no reliable method has been found to predict the fate of femoral neck fractures preoperatively. Attempts at a prognostic evaluation by means of arteriography, venography, determination of the pressure in the intramedullary cavity of the femoral head, oxygen tension in the head, and various kinds of scintigraphy have been reviewed by Huith (1965), who states that these methods can predict the fate of the head in 80–90 per cent of cases. The methods mentioned have not attained much clinical significance, but they

have contributed to the opinion that of the fractures is determined at the of the accident, everything depending remaining vascularity of the femoral

Other authors, as mentioned below the opinion that transosseous nutrition might keep the femoral head alive. B. Abram (1964) on histological examination of the femoral heads from five fractures with late segmental collapse found "clear of an initial severe ischaemia of the fragment and with subsequent revascularization across a healed fracture." In the revascularizing process, however had to reach the most proximal and superior quadrant of the femoral head prior to collapse. Catto (1965) found in 12 femoral heads, resected for secondary hip arthritis because of late segmental collapse, histological evidence of revascularization: seven out of 12 heads revascularization reached the fovea of the femoral head.

Riggins et al (1974) in an assessment of the circulation in the femoral head of the subcapitally osteotomized through the femoral neck, with subsequent revascularization of the completely detached femoral head using threaded pins, showed, by means of 18-F scintigraphy, tetracycline labelling

(1977) using preoperative scintigraphy in cases of fractures of the femoral neck found at a 2 year follow up that primarily negative scintigrams (with avascularity confirmed by histological examination of core biopsies from the femoral heads) after reduction and pinning of the fractures were converted in positive scintigrams. They suggested that this indicated revascularization of the femoral head.

Arnoldi & Lemperg (1977) in a series of displaced femoral neck fractures, measured the intraosseous pressure of the femoral head after reduction of the fracture. A larger number of cases with pulseless pressure curves showed no evidence of avascularity at the time of follow up which was taken as evidence of revascularization.

Klenerman & Marcuson (1970) in a morphological and radiological study of fractures of the femoral neck stated that the fracture pattern is always the same: the fracture line passing from the epiphyseal scar on the superior aspect of the neck along the ascending trabeculae to the calcar.

It seems to us that one can ignore the radiological angulation or the position of the fracture line and concentrate only on the fracture displacement. Our results show that the amount of fracture displacement determines the prognosis. The results of partly displaced Garden stage 3 fractures are significantly better than the results of fully displaced stage 4 fractures.

Skill and training are required for the exact reduction of a displaced femoral neck fracture. Twenty surgeons at different stages in their training have performed the

Example of a poorly reduced fracture with displacement and insufficient bone contact

cal examination of the femoral heads months that revascularization of totally avascular heads had occurred out of seven cases. Meyers et al

Radiological results in 26 poorly reduced fractures (according to Garden). Significance of ad latus displacement and insufficient bone contact

		Ad latus displacement and insufficient bone contact	Non union	Late segmental collapse
Fractures	20	20	14	6
	6	0	0	0
	26	20	14	6

Exact test $P < 0.001$

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Chi square test $P < 0.001$

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It is still an open question whether the type of malreduction is more important than an accurate angle after reduction as it seems to substantially influence the possibility of transosseous stabilization. This might in fact be deduced from the results of the present study. Six out of 26 insufficiently reduced fractures united uneventfully without any risk of late segmental collapse. Compared with the other 20 fractures which developed non-union or late segmental collapse, these fractures were all reduced at a backward angle of more than 30 degrees, but logically there was firm contact over the fracture area, a finding which was not entered in the other 20 cases where *ad* dislocation and gaps in the fracture were evident. This demonstrates that these types of malreduction are of great importance. This is in agreement with Barnes et al (1973) who after open reduction placed femoral neck fractures added iliac graft to the posterior gap in the femoral neck in order to obtain substantial bone contact over the whole fracture area. This study significantly reduced non-union from 12 to 3 per cent. Substantial bone contact was also advocated by Deyerle (1966), who obtained this by extensive impaction of the fracture.

Multiple pinning in the treatment of femoral neck fractures was recommended by Jensen (1935), and Telson & Ransohoff (1951), a few years after the introduction of the Smith-Petersen nail (Smith-Petersen et al 1931). We prefer the multiple pinning method because it seems to minimize the risk of jeopardizing possible transosseous stabilization. Rotation of the femoral neck is less liable to occur if several nails are used instead of a single one. Loosening of one nail in the osteoporotic bone of the femoral neck will deteriorate fracture fixation. This is likely to happen if several nails are used. A survey of the literature shows that the results of multiple pinning are superior to those obtained by a single nail or screw

with or without anchorage in the lateral cortex (Table 6).

In our experience application of percutaneous multiple pins in the treatment of femoral neck fractures is to be recommended because it is a minor operative procedure with minimum loss of blood. Furthermore the infection rate is less than 1 per cent and the mortality rate compares fairly well with the results of Barnes et al (1976) in his large series, except for the 1 month mortality rate where we obtained significantly better results ($P < 0.05$).

At the same time, the method also results in a low frequency of non-union and late segmental collapse compared with other methods. During the study period only 16 per cent of the patients with late segmental collapse needed a secondary hip replacement compared with 75 per cent of the patients with non-union. Non-union is thus considered the more serious failure in the early postoperative period.

CONCLUSIONS

- 1) The degree of primary fracture displacement is of prognostic value.
- 2) Good fracture reduction leads to a low failure rate.
- 3) The Garden criteria for poor reduction should be supplemented by consideration of other forms of malreduction.
- 4) Severe fracture dislocation should be handled by a skilful and experienced surgeon.
- 5) Non-union is a more disastrous complication than late segmental collapse.
- 6) Percutaneous multiple pinning is a minor operative procedure resulting in stable fractures.

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Table 6 Comparison of the results of different methods of osteosynthesis

Author and no. of fractures	Year	Method of pinning	Fracture type	Non- union	Late segmental collapse	Total failure rate (%)
Barnes et al (255)	1976	single nail	Garden 3 & 4	47 %	21 %	68 %
Garden (332)	1971	cross screw	Garden 3 & 4	33 %	21 %	54 %
Smyth et al (45)	1964	cross-pins and plate	Garden 3 & 4	18 %	40 %	58 %
Barnes et al (304)	1976	sliding nail-plate	Garden 3 & 4	28 %	19 %	47 %
Brown & Abrams (146)	1964	sliding nail-plate	Garden 3 & 4	23 %	27 %	50 %
Boyd & Salvatore (160)	1964	sliding nail-plate	Pauwels 2 & 3	11 %	33 %	44 %
Fractures total 1242		Average failure rate				53 %
Deverle (35)	1966	multiple pins	all types	0 %	6 %	6 %
Metz et al (63)	1970	multiple pins	all types	5 %	12 %	17 %
Strange (42)	1969	multiple pins	all types	13 %	5 %	18 %
Arnold et al (505)	1974	multiple pins	Garden 3 & 4	15 %	12 %	27 %
Present series (112)		multiple pins	Garden 3 & 4	14 %	11 %	25 %
Fractures total 757		Average failure rate				18 %

Chi square test $P < 0.001$

operations in our series. This might be one reason why 24 per cent (39/165) were insufficiently reduced. Acknowledging the necessity of good reduction to obtain good results in displaced fractures of the femoral neck, no inexperienced surgeon should be allowed to undertake the reduction manoeuvre, at least not in severely displaced fractures.

The criteria for reduction used in study was introduced by Garden (1971) deals with the magnitude of angulation in frontal and lateral view compared with alignment index of 160/180 the limit of good reduction being 150/190. However, index does not take into account other of malreduction such as istus dislocating insufficient contact between the

REPLACEMENT WITH THE CHRISTIANSEN ENDOPROSTHESIS IN ACUTE FEMORAL NECK FRACTURES

A Retrospective Follow-up Study

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Abstract

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Two examinations have been compared. The patients' personal opinion of the results of the operation did not change between the time of the first and second follow-up examinations. However, the objective results showed a deterioration in function (according to Stinchfield's hip assessment scheme) with increasing follow-up time. This deterioration in rating was mostly caused by reduced walking ability. X-ray study of the hips showed an increasing frequency of acetabular protrusion, and settling and loosening of the prosthetic stem. No clear correlation between X-ray findings and clinical results could be found. We conclude that the serviceability of the prosthetic operation is apparently good despite the objective evidence of progressive deterioration both in the grading of the results and in the X-ray findings.

Key words: femoral neck fractures, primary prosthetic replacement, radiography, surgery

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Results following primary prosthetic replacement for acute, displaced femoral neck fractures have, in our experience been variable and in many respects comparable to internal fixation (Søreide et al 1975, Søreide et al 1979). However, the follow-up time has been short for all our patients.

Studies of long-term results after prosthetic surgery are few. The general opinion is that the results of replacement of the femoral head worsen with time. Theoretically, joint narrowing or acetabular protrusion, induced with prosthetic replacement, could be avoided using Christiansen's

trunnion bearing hip prosthesis, in which a joint connection is introduced between the prosthetic stem and the headpiece of the prosthesis. With this arrangement, and with the femur moving in the sagittal plane, most of the movement should occur in the trunnion bearing with the prosthetic head lying at rest in the acetabulum.

We reported, in 1975, the results of a retrospective study of replacement with the Christiansen endoprosthesis in 123 patients with acute femoral neck fractures (Søreide et al 1975). In order to obtain information about time-induced changes, both as regards function and X-ray appearance, we have



Figure 1 Christiansen's endoprosthesis in a good position seen 9 months after the operation

recently re-evaluated the available patients from the 1975 study and compared the results of the two consecutive examinations.

PATIENTS AND METHODS

A total of 123 patients with an acute femoral neck fracture (16 men and 107 women, mean age 80.5 years) were treated by primary prosthetic replacement from 1971-1973 using the Christiansen transtion bearing hip prosthesis with a metal cup (same model for all operations, see Figure 1). Of the original 123 patients 70 had died (according to information obtained from the Official Registrar). The remaining 53 patients were asked to come for clinical examination and X ray review during the summer of 1978.

Thirty-four patients were seen in our hospital and examined both clinically and roentgenologically. Six patients were visited in their homes and a clinical examination performed.

Table 1 The patient's personal opinion of operative results

	Follow-up I	F*
Good	24	2
Acceptable	10	1
Poor	6	1
No information	11	1
Statistical difference	n.s.	

Two patients with deep infection were transferred to geriatric institutions (see Results). One was living too far away and was not contacted. The remaining two patients could not be traced.

The mean follow-up time for the 34 patients was 67.4 months (range 34-87 months). The mean follow-up time for the same patients in the 1975 study was 15.2 months (range 2-35). The results of the two examinations were compared, using the Chi-square test otherwise stated.

RESULTS

Patient's personal opinion

The patient's personal opinion of the result of operation was obtained at postoperative examination compared with the same patient's opinion at the time of the first examination. The results are given in Table 1. There is no statistically significant difference between the two

Walking ability at the second examination

The status of the 40 personally examined patients concerning walking ability and need for walking aids was recorded. In the first examination half of the patients are severely handicapped and more than 50 per cent (22/42) state that their reduced walking ability was connected with the operation. (For comment see Discussion).

Infections

As already stated, two patients were transferred to geriatric institutions. These

2 Objective hip assessment according to Stinchfield's classification system at the first and second examinations

	Follow-up I	Follow up II
no infection	11	4
deep infection	19	18
shallow infection	5	13
total	2	7

cal
ice

$P = 0.006$

two patients who developed deep infection postoperatively and have been examined previously (Søreide et al 1975). All patients have lived more than 6 years after a Girdlestone hip and persisting infection. No other patients with late infection were found.

Objective hip assessment

Objective hip assessment was performed according to the Stinchfield hip assessment scheme (Stinchfield 1957). The second examination was made on 40 patients, plus the two patients with deep infection who were graded as 'deep'. The previous examination had been made on 37 (including the two patients with deep infection) of the 42 patients. The results are given in Table 2. The results of the first examination were significantly better ($P = 0.006$) than the results in the same patients examined 52 months later.

The mean score for walking ability according to Stinchfield's hip assessment scheme was reduced from 3.5 points at the

first examination to 2.7 points, a reduction of 0.8 points, the score for hip movement was reduced from 4.7 points to 4.2 points, i.e. 0.5 points, and the pain score was reduced from 5.2 points to 4.7 points, i.e. 0.5 points. Thus, the poorer results are caused by a general reduction in walking ability, hip movement and pain score, with the most marked reduction being in walking ability.

Contractures

In 40 of the patients seen at the second follow-up, flexion contractures of varying degrees were revealed in 14, and 4 patients had combined contractures. Of these 40 patients, 35 had been examined earlier. At that time, only one patient with a flexion contracture was found. Thus, there were significantly more contractures ($P < 0.001$) at the later follow-up examination. However, compared with the contralateral (non-operated) hips, where contractures were found in 9 patients, the difference is statistically not significant ($P > 0.10$).

Range of movement

The range of movement in the 40 recently examined patients was compared with the range of movement recorded earlier in 35 of these patients. The results are given in Table 3. As shown, a significant reduction (t -test) in movement was found with increasing follow-up time except for flexion and lateral rotation.

The range of movement recorded at the second examination was also compared with the range of movement in the contralateral

Table 3 Range of movement in the operated hips at the first and second examinations (mean \pm s.d.)

	Follow up I $n = 35$	Follow up II $n = 40$	Statistical difference
no infection	96 \pm 20	91 \pm 25	n.s.
infection	4 \pm 5	-4 \pm 16	$P = 0.003$
flexion	32 \pm 14	19 \pm 17	$P < 0.001$
extension	33 \pm 10	25 \pm 12	$P = 0.002$
lateral rotation	21 \pm 12	16 \pm 13	$P = 0.02$
medial rotation	23 \pm 14	23 \pm 18	n.s.

and non-operated hip (excluding 4 patients with bilateral hip surgery). The results are given in Table 4. There was a significantly better range of movement in the non-operated hips than in the endoprosthetic operated hips (t test).

X-ray examinations

X-ray examinations were performed in 34 of the recently examined patients and the results were compared with those obtained previously in 30 of these patients.

The statistical analysis which was used in this connection is associated with the follow-up time aspect. Thus, we have to test the hypothesis that "no aging" occurs (i.e. the condition occurs haphazardly) against "aging", using methods from the statistical theory of reliability and life testing based on the Weibull model (Mann et al. 1974).

Acetabular protrusion Acetabular protrusion (Figure 2) was found in 8 of the recently examined patients (mean 9.8 mm, range 3–20 mm). At the earlier examination, only one showed acetabular protrusion (7 mm). The statistical analysis showed that there was a significantly increased frequency ($P < 0.05$) of acetabular protrusion with increasing follow-up time.

The pain score for the patients with acetabular protrusion was not significantly different ($P > 0.10$) compared with the pain score for patients without protrusion. The range of movement was also the same ($P > 0.10$ t test).

Settling of the prosthetic stem There was in the recently examined group no evidence of settling but there were patients with signs of settling at examination. This difference is significant ($P < 0.01$).

Loosening of the prosthetic stem Loosening of the stem (Figure 3) was clinically and roentgenologically not seen in any patient at the second examination. In addition, loosening was suspected in other patients on the basis of studies. None of the studies showed evidence of loosening. This difference is statistically significant ($P < 0.01$).

Results of the questionnaire

The results of the questionnaire are given in Table 5. The results of the questionnaire are given in Table 5.

DISCUSSION

The usefulness of primary arthroplasty for femoral neck fractures is a matter of debate. Two factors are acceptably important: mortality rate postoperatively and expected serviceability of the patient exceeding a certain period of time. The usefulness of this operation with respect to postoperative morbidity and to be well documented, both (Sörense et al. 1975, Sörense & 1979) and prospectively (Sörense et

Table 4. Range of movement in the operated hips at the second examination compared with movement in the contralateral non-operated hips (mean \pm s.d.)

	Operated hips $n = 40$	Non-operated hips $n = 36$	Statistical difference
Flexion	91 \pm 25	105 \pm 22	$P = 0.001$
Extension	-4 \pm 16	1 \pm 13	$P = 0.01$
Abduction	19 \pm 17	26 \pm 14	$P = 0.01$
Adduction	25 \pm 12	29 \pm 12	$P = 0.02$
Medial rotation	16 \pm 13	26 \pm 15	$P < 0.001$
Lateral rotation	23 \pm 18	31 \pm 16	$P = 0.001$



Acetabular protrusion of marked degree months after the prosthetic operation



Figure 3 X ray appearance of a loose prosthesis with a radiolucent zone around the bone cement and distal migration of the prosthetic stem (63 months postoperatively)

Table 5 The results of the questionnaire (patients not examined)

Pain	Severe	0
	Moderate	3
	Slight	3
	No pain	3
Walking ability	Bedridden	1
	Indoors without help	1
	Outdoors without help	3
	Normal for age	4
Operation area	Dry, no pain	9
	Red, painful \pm drainage	0

Concerning the serviceability of the prosthetic operation we are not able to draw a final and consistent conclusion. Based on the patients' personal opinion it seems reasonable to maintain that the prosthesis has functioned well for the individual patient as this opinion did not change with increasing observation time. As shown in the recent examination, half of the patients are severely handicapped, and they stated that their reduced walking ability was connected with the operation. However, we are not able to accept this last statement, firstly, because the general opinion about the operation was good, and secondly, because many of them had been admitted to geriatric institutions for reasons other than the prosthetic operation. The finding that the frequency of contractures was the same in the operated and non-operated hips also supports this view. In this respect, we also find support in the conclusions of Hinchey & Day (1964) who stated that reduced function in their patients was related to a new disabling disease or to slowly developing weakness. Classification of the results (after Stinchfield) clearly demonstrated deterioration in function with increasing follow-up time. Although the grading of the results decreased it is clear that a major part of the reduction can be explained by age-induced functional changes, i.e. reduced walking ability. However, the range of movement in the prosthetic operated hips was less than in the non-operated contralateral hips, which indicates that the lower grades were also caused by the operation.

The X-ray findings demonstrated related changes in the h.p.s. An increased frequency of acetabular protrusion, ~~seen~~ the prosthetic stem and loosening of diaphysis was found. Acetabular protrusion not associated with increased pain or limitation in hip movement. Our findings supported by Whittaker *et al.* (1972), Hinchey & Day (1964) who also found the clinical results did not correlate with degree of protrusion in their patients.

The number of patients with and/or loosening of the prosthetic stem too few to draw any conclusions with to pain and reduced function. In the literature there is also some conflict in this respect. Some authors state that settling is a symptomless phenomenon (Lundholm *et al.* 1976), not the cause of pain and impaired function (Polyzoides 1971), and that settling less than 20 mm does not affect motion of the hip (Steen Jensen & Holsten 1964). On the other hand, Harris (1966) in his series of 27 patients with sinking prostheses demonstrated a very high incidence of disability in this group of patients. Sørensen & Møller-Nielsen (1972) found poor fixation of the prosthetic stem in the femoral shaft was connected with late post-operative view also supported by Whittaker *et al.* (1972).

It seems reasonable to conclude that the serviceability of the prosthetic operation is acceptable despite the objective evidence of progressive changes in the acetabulum and the proximal femoral shaft. These changes show no correlation to symptoms. However, these results should be viewed with caution because of the long survival of patients treated with primary prosthetic replacement (Soreide *et al.* 1979), a survival exceeding the period of observation and follow-up both in this study and other studies for patients below the age of 60 years.

The Christiansen endoprosthesis was primarily constructed to exclude the possibility of at least minimize the problem of acetabular erosion or protrusion. From this study it

to conclude that even with this prosthesis there is an increasing frequency of protrusion with increasing follow-up time. In the 1975 study with a mean follow-up of 15 months, the frequency of protrusion was 2.5 per cent (1 of 42 patients). At the later examination (mean follow-up of 67 months) the frequency had increased to 24 per cent (8 out of 33 patients). The frequencies of protrusion reported by other authors range from 4 per cent (mean follow-up time 40 months) to 38 per cent (follow-up time of 24–60 months) for the Austin-Moore or Thompson prosthesis (Polyzoides 1971, Whittaker et al 1971, Andersson & Møller Nielsen 1972, Steen et al 1972, D'Arcy & Devas 1976, Beckenbaugh et al 1977). Thus, based on our experience of patients operated with the Christiansen prosthesis followed for more than 5 years, we conclude that although theoretically the trunnion bearing of the Christiansen prosthesis does not seem to increase the frequency of acetabular protrusion, the question which remains to be answered is whether there is a correlation between the frequency of X-ray changes and time. Important in this connection is the finding of Hinchey & Day (1964), i.e. that deterioration occurred primarily during the first 4 years after that period the results did not deteriorate further (follow-up time 11 years). This view is supported by Salvati & Wilson (1973). Our study also shows that the classification of the results following prosthetic surgery in hip patients according to the existing hip replacement schemes does not reflect the actual functional status of the patients. It is important that for this group of patients, assessment of hip function should be performed by a disability rating.

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MECHANICAL STRENGTH OF JEWETT AND McLAUGHLIN HIP NAIL PLATES MANUFACTURED FROM COBALT-CHROMIUM-MOLYBDENUM ALLOY

A Biomechanical Study of Unstable Trochanteric Fractures. IV

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Jewett and McLaughlin hip nail plates were mechanically tested, and the mode of failure of both types of implants are described and discussed in this communication. Mechanical problems at the nail plate junction in the present design of the McLaughlin implant seem to make it unsuitable for internal fixation of unstable trochanteric fractures, but Jewett nail plates with angles of 125° or 135° can be recommended for this purpose.

Key words: biomechanics, fracture fixation, femoral neck fractures, stress, mechanical.

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In a clinical series it is known that Jewett nail plate fixation of unstable trochanteric fractures is followed by mechanical failures such as bending or breakage of the nail or in 5-30 per cent of cases (Cleveland et al 1959, Dimon & Hughston 1967, Evans et al 1976, Jacobs et al 1976, Laros & Moore 1975, Montz & Scheuba 1970, Parker 1955, Sarmiento 1967).

The comparative figures for McLaughlin nail plates have been reported to be 6-46 per cent (Bremner & Graham 1958, Clawson 1977, Cram 1955, Foster 1958, Friedenberg et al 1972, Jensen & Michaelsen 1975, Laros & Montz 1974, McLaughlin & Garcia 1955, Sarmiento 1963).

It has been emphasized that unstable trochanteric fractures with no bony support at the calcar femorale make great demands on the strength of the implant. The hip joint load is transmitted through the implant to the femoral shaft (Dimon 1973, Fielding 1973, Frankel 1963, Johnston 1973, Jensen 1978b,

Jensen et al 1978, Massie 1962, Scheuba 1970, Sonstegard et al 1974).

Brettell (1970) and Martz (1956) pointed out the necessity of examining the mechanical strength of different implant designs. Implants for internal fixation of unstable trochanteric fractures have been the subject of a number of investigations (Foster 1958, Frankel 1963, Holt 1963, Kaufer et al 1974, Martmek et al 1976, Martz 1956, Richter & Peter 1975, Sauer et al 1977, Schottle et al 1977, Sonstegard et al 1974, Sunami et al 1977). The majority of the papers from Germany, however, reported experiments with AO-angle plates or intramedullary rods.

The purpose of the present study was to examine the mode of failure of Jewett and McLaughlin nail plate implants manufactured from Cobalt-Chromium-Molybdenum alloy (Vitallium®) by Howmedica Inc., USA and Ireland. The principal differences in the engineering design of these two implants is that the Jewett nail plate is cast as a one-piece

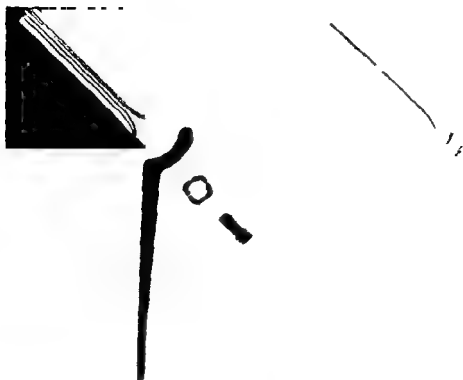


Figure 1 The components of the McLaughlin hip nail plate before and after assembly

implant, whereas the nail and plate of the McLaughlin hip implant is assembled by means of a top bolt with the interpositioning of a washer (Figure 1)

MATERIALS AND METHODS

From recent photoelastic studies (Jensen 1978a, b) the ideal experimental position of an implant for testing was calculated to be at an inclination of 11° to the vertical.

The purpose of this study was to test Jewett and McLaughlin hip implants with the nail plate angles listed in Table 1. In order to obtain comparable results the moment arm (MA) about the intersection between the back of the plate and the centre-line of the nail was kept constant. According to Figure 2 the nail length (L_N) could thus be calculated to be

$$L_N = \frac{MA}{\sin \alpha} \quad \text{for the Jewett nail plates}$$

and

$$L_N = \frac{MA}{\sin \alpha} + 11 \quad \text{for the McLaughlin nail plates}$$

($\alpha = 169^\circ$ — nail plate angle $r = 137^\circ$ — nail lengths corresponding to a moment arm mm are shown in Table 1)

Experiments were performed on Chromium Molybdenum (Vitalium® Hoe Inc) implants with tritin nails of the 6 lengths and 4- or 5-hole plates (numbers 6403-1 6378-0 6633-1 Hoe Inc). The McLaughlin implants were together by means of a cannulated top bolt the insertion of a washer between the extensions of the plate and the top bolt. McLaughlin experiments the plate was 14

The implants were screwed to a steel bar and mounted in a base clamp inclined the vertical. The steel bar did not support proximal 25 mm of the plate. Thus arm was mounted in a universal testing machine Zwick GmbH & Co W Germany electronic force measurement (0-10 kN) deflection of the implant was measured linear displacement transducer (LYDT Schaeffert Engineering USA) as shown diagram in Figure 3

At the top of the nail a polished Vitalium

Table 1. Applied nail plate angles, moment arms and nail lengths

Implant	Nail plate angle	Moment arm about intersection (mm)	Moment arm about nail-plate junction (mm)	Nail length (mm)
Jewett	125°	41.4	41.4	59.5 (2.34")
	135°	41.4	41.4	74.0 (2.91")
	140°	41.4	41.4	85.3 (3.36")
	150°	41.4	41.4	127.0 (5.00")
McLaughlin	126°	41.4	50.7	74.4 (2.93")
	132°	41.4	49.7	82.6 (3.25")
	138°	41.4	48.4	94.0 (3.70")
	150°	41.4	45.8	140.7 (5.54")

tion of the moment arm, the displacement of the nail tip was measured with a linear displacement transducer (LVDT E 1000, Schaeffgen, USA).

with the results of photoelastic experiments on two-dimensional models of hip (Jensen 1978b) the nail was fitted with a gauge 25 mm from the nail plate junction (J-3, TML, Japan) and an additional strain gauge was placed proximal to that (QFLA-1, Japan). Similarly the plate was fitted with strain gauges (QFLA-3, TML, Japan) 25 mm from the nail plate junction. The strain gauges were bonded to the metal surface with a

Industries, Peckel Division, Holland). The strain gauges were temperature compensated for steel and the experiments were performed over short time intervals.

Any of the measurement signals could be amplified (W-100 and W-101, C Worsøe, Denmark, and KAS Elektroniklab, Denmark) and converted into microvolts by digital voltmeters (Intersil Inc, USA, and KAS Elektroniklab, Denmark).

Load was applied to the tip of the nail by

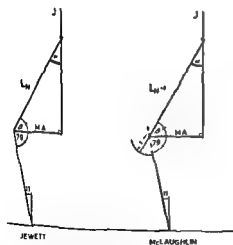


Figure 2. Mathematical calculation of nail length
 $\alpha = 169^\circ$ — nail plate angle
 β — nail plate angle — 79°
 l — applied force perpendicular to moment arm
 m — moment arm
 n — nail length
 r — radius of curved extension of plate

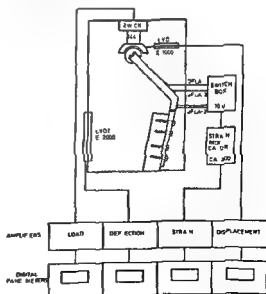


Figure 3. Diagram of the experimental arrangement.

advancing the crosshead of the testing machine at a rate of 12 mm per minute. Recordings of the measurements were done at static loads for every 0.5 mm deflection of the implant. The testing was completed when 11 mm of deflection was obtained.

The microvolt recordings were converted into Newtons, millimeters and microstrain ($\mu\epsilon$), respectively, and load-deflection diagrams and load-strain diagrams constructed. Five experiments were performed with implants in each of the angles mentioned in Table I and the mean curves were calculated for each implant angle.

The bending moment about the intersection between the back of the plate and the centre-line of the nail was calculated according to the equation

$$M_b = J \times (MLA + \Delta MLA)$$

where M_b = bending moment, J = applied load as measured, MLA = moment arm = 41.4 mm, ΔMLA = elongation of the moment arm as measured. The bending moment about the nail plate junction in McLaughlin implants was

calculated according to the same equation with the moment arms listed in Table I.

From these calculations moment diagrams and moment-strain diagrams were constructed. In all diagrams the yield point, when metal undergoes a permanent plastic deformation, was defined as the point where the straight line on the graph was transformed into a curved line.

RESULTS

The first diagram to consider is the load-deflection diagram for the complete set of hip nail plate implants as demonstrated in Figure 4. The diagram shows mean curves calculated from recordings of the applied load with simultaneous reading of the deflection at the tip of the nail.

It is seen that the Jewett implants have two yield points, while as many as three points are encountered for the McLaughlin

JEWETT — YIELD POINTS

125° = 1500 N	125° = 1830 N
135° = 1220 N	135° = 1820 N
140° = 870 N	140° = 1150 N
150° = 950 N	150° = 1200 N

McLAUGHLIN — YIELD POINTS

126° = 225 N	126° = 390 N	126° = 75
132° = 230 N	132° = 330 N	132° = 75
138° = 250 N	138° = 380 N	138° = 75
150° = 280 N	150° = 640 N	150° = 75

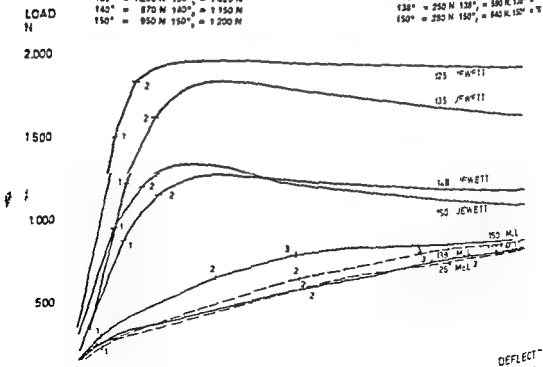
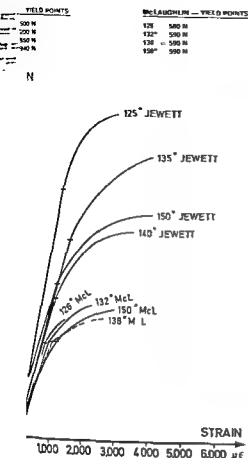


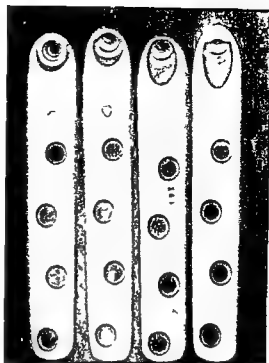
Figure 4 Load deflection diagrams for trifen hip nail plates of the Jewett and McLaughlin types



5 Load strain diagrams for trifen hip

These yield points are caused by parts of the implants undergoing plastic deformation at different

In the Jewett series the low yield points are considerably lower in implants with a nail plate angle of 140° or 150° than in those with a 125° or 135° nail plate angle, the latter being the strongest. The load-strain diagram for the trifen hip nails shown in Figure 5 was obtained from recordings of the load with piezoelectric readings of the surface strain measured by strain gauges on the nail 25 mm from the nail plate junction, as this was in all cases the gauge giving maximum recordings (indicating that the maximum deformation occurred beneath it). It is seen that the nails in Jewett implants underwent plastic deformation at surface



6 Four trifen hip nails

plastic deformation

at strains of 1 250–1 650 μE . The yield loads for Jewett implants were taken as values corresponding to the lowest yield points on the load-deflection diagram in Figure 4, and with the same distribution. The low yield points on the Jewett graphs were thus caused by bending of the trifen hip nails.

Concerning the high yield point on the Jewett graphs these were also found to be considerably higher when the nail plate angle was 125° or 135° than when it was 140° or 150°. The explanation is that the design of the implants involves a rather large counterbore in the upper part of the plate to allow space for the tool used during the operative insertion of the nail into the femoral neck. As seen from Figure 6 this involves a considerable reduction in the cross section of the 140° and 150° implants and the plates bent in the area where the lower edge of the nail joins the plate (Figure 7).

According to Figure 8 the varus dislocation

Table 3 Calculated bending moments about the strain gauge centre on the triffin hip nails

Nail plate	Nail plate angle	Moment arm	Elongation of moment arm ($\Delta M A$ mm)	βx	αx	Load J (Newton)	Bending moment (M_B)
		M.A. (mm)					
Jett	125°	41.4	0.07	43° 8	46° 2	1 500	35.0 Nm
	135°	41.4	0.80	53° 5	36° 6	1 220	33.3 Nm
	140°	41.4	1.28	58° 5	31° 5	870	25.7 Nm
	150°	41.4	2.40	69° 0	21° 0	950	33.0 Nm
McLaughlin	126°	50.7	5.76	39° 2	50° 8	590	21.9 Nm
	132°	49.7	6.04	45° 5	44° 6	630	24.1 Nm
	138°	48.4	10.31	51° 1	38° 9	590	25.4 Nm
	150°	45.8	8.60	66° 0	24° 1	640	28.3 Nm

ling superimposed on a preload caused the muscle traction (Johnston 1973, 1966, Paul 1967, 1971, Rydell 1966). hip joint load during normal walking was estimated by Paul (1967, 1971, 1976) and III (1966) to be 3–5 times the body weight corresponding to a hip joint load of at 180–200 kilograms.

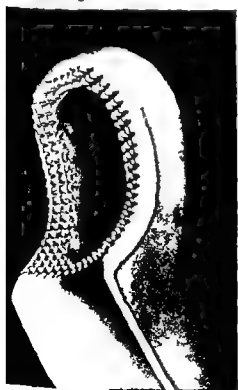


Figure 9 McLaughlin hip nail plate. The small serrations of the curved plate port on flattened at the lower contact point with the plate extension bends at the same level.

The present study of the mechanical strength of hip implants is a static study which does not take into account the muscle traction and the repetitive loading of the hip joint. A static study however reveals the mode of failure of the various components of the implants and the corresponding loads and gives information about how the implants act *in vivo* and about the risk of fatigue failure (Dumbleton & Black 1975, Frankel & Burstein 1971, Swanson & Freeman 1977). In a recent paper the author (Jensen 1978b) recommended the steepest possible nail plate angle for the internal fixation of unstable trochanteric fractures. These recommendations were based on two-dimensional photoelastic studies of Jewett implants and agree well with theoretical engineering principles. The present series however revealed that the least angled Jewett



Figure 10 McLaughlin hip nail plate. The interposed washer is bent concavely and is thinner compared with an unused washer.

nail plates were the strongest. The loads causing permanent plastic deformation of the trifen nails never amounted to more than about 75 per cent of the hip joint load in the human body during walking or standing. The loads causing failure of the plates were also found to be higher in the low angle Jewett implants and in the 125° and 135° implants the values were fairly close to the hip joint load in slow walking on a level surface (Paul 1976, Rydell 1966). The lower strength of the high angled implants is due to their design with a large counterbore in the upper part of the plate resulting in a reduction in the cross-sectional area, a fact which was not taken into consideration in the photoelastic studies (Jensen 1978b).

Recent biomechanical experiments on Jewett implants (Frankel 1963, Sonstegard et al 1974) have reported loads to failure which correspond with those in this series, whereas Sunami et al (1977) have stated lower values. The mode of failure for the plate in the present series corresponds with that found by Kaufer et al (1974) but a comparison cannot be made with Holt's series (1963) as the design has been altered since Grover, however, as early as 1966 warned against holes and notches in the implants as these might lead to stress concentrations and unexpected failures at relatively small loads.

From the experiments it can be concluded that Jewett implants with angles of 125° or 135° should be chosen for the internal fixation of unstable trochanteric fractures, where the implant is transmitting the entire hip joint load. In the clinical aftertreatment and follow up examination very small varus angulations of less than 5° should be looked for, because this indicates that the yield point of the implant has been exceeded. As a consequence of this the risk of fatigue failure caused by cyclic loading during walking becomes very high.

In the experiments with the McLaughlin implants the loads causing failure were considerably lower than in the Jewett series. This corresponds with the results reported by Holt (1963) and Sunami et al (1977). Richter

& Peter (1975) however claimed considerably higher failure loads for McLaughlin implants, but performed the experiments on two-fragmentary trochanteric fractures, the load is mainly transmitted through bone.

The most important observation from the McLaughlin series was, however, that the nail plate junction only withstands ca. 225–280 N. At this load there is deformation of the small knobs of the curved extension as well as of the nail base. This is probably due to the very small contact area and is followed by successive bending of the washer and the threads of the top bolt. Other papers (Foster 1958, Martz 1958, Schatz 1970) have claimed that the junction between the nail and the plate is a weak point. Furthermore, it has been demonstrated in a clinical series (Bremner & Graham 1957, Clawson 1957, Friedenberg et al 1972, Foster 1958, Laros & Moore 1974, McLaughlin & Garcia 1955) that varus angulation at the nail point appears rather frequently. Jensen & Michaelsen (1975) thus reported that the varus dislocation in 25 per cent of the trochanteric fractures fixed with the McLaughlin implant.

A small varus angulation may be of no clinical significance but the present series also revealed that even a roentgenologically undetectable varus angulation means plastic deformation of the components of the nail plate junction. The consequence of this loading is progressive deformation and loosening.

For the McLaughlin implants, however, three yield points were encountered. The first component undergoing plastic deformation was the trifen nail at loads of about 600 N although the geometry of the cross section has been considered among the strongest available (Laing & O'Donnell 1967). The final component to deform was the curved extension of the plate which bears loads of about 750 N.

In summary the experiments on the McLaughlin nail plates demonstrate that a varus angulation of about 8° in

ing of the nail plate junction and of the nail, while a varus angulation of 12° also includes bending of the nail part of the plate. As the loads for deformation of the McLaughlin nails are less than half of the hip joint load during slow walking on a level surface, it is in agreement with Ghista & Elangovan (1977), who claimed the design to be safe on the basis of theoretical calculations. In the treatment of unstable trochanteric fractures the implant transmits load from the hip joint to the femoral shaft during the healing period of the fracture. The present McLaughlin implant is therefore unsuitable for internal fixation of trochanteric fractures, if the osteosynthesis is delayed by early weight-bearing as is often recommended (Jensen et al 1978). The remaining of the nail plate junction is usually a matter of urgency, but the remaining of the entire implant should also be considered.

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DIFFERENTIATED CARE OF HIP FRACTURE IN THE ELDERLY

Hospital Days and Results of Rehabilitation

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Two series of elderly patients with hip fracture were compared with regard to hospitalization time and social situation after discharge from hospital. Our series included 131 patients from 1966 with late weight bearing and 362 patients from 1972-1973, mobilized with early weight-bearing. Approximately two-thirds of the patients came from their own homes and one-third from institutions. The mean hospital stay for patients discharged to their own homes was 7 weeks in 1966 and 3-4 weeks in 1972-1973. This decrease in hospitalization time did not cause any increase in the proportion of patients

mobility at 2 weeks proved to be a better indicator of the patient's chances of returning home. This may be a helpful guide when planning the aftercare of these patients.

* **Key words:** aftercare, early mobilization, femoral neck fractures, hip fractures, hospitalization, rehabilitation

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In the industrialized countries of the West, the incidence of the hip is becoming increasingly common because of the greater number of elderly individuals in the population. This trend, which will continue over at least the next couple of decades, is causing a severe strain on medical and social facilities (Schenk 1956, Gylling 1960, Alffram 1964, Bauer 1969 and 1978, Thomas & Stevens 1974, British Medical Journal 1976, Gallannaugh et al 1976, Ødegård & Unsgård 1978, Steen & Tøndevold 1980). The demand for hospital beds has been counteracted by shorter periods of hospitalization. In Lund, for example, hospitalization for hip fracture in the Department of Orthopaedics dropped from about 20 weeks in 1950 to 4 weeks in 1970 (Borgquist 1974).

This study was undertaken to assess whether shorter hospitalization following fracture of the hip had caused a correspondingly greater utilization of secondary rehabilitation facilities. The comparison was made between two groups of patients from the same population, admitted for fresh fracture of the hip in 1966 and in 1972-1973, respectively.

PATIENTS AND METHODS

The clinical series included all residents of the primary catchment area of Lund, over the age of 50 who had sustained a hip fracture and were admitted to the Department of Orthopaedic Surgery, Lund. This area had a total population of 148 692 inhabitants in 1966 and of 181 387 inhabitants in 1973. The number of patients was 131 in 1966 and 362 in 1972-1973. Patients from

Table 1 Patients with hip fractures grouped according to age, sex type and year of fracture

Age	1966				1972-1973			
	Cervical		Trochanteric		Cervical		Trochanteric	
	M	F	M	F	M	F	M	F
50-64	2	6	2	1	7	15	6	1
65-79	4	18	1	24	19	57	27	6
> 80	5	23	7	18	17	67	15	7
Total	11	67	10	43	43	139	48	14

the psychiatric hospital in Lund were excluded from these series.

The mean age of the patients was 77 and 79 years in the 1966 and 1972-1973 series, respectively, women outnumbered men by three to one and there was a slight preponderance of cervical fractures in women (Table 1).

Socio-medical grouping In both series about two-thirds of the patients lived at home at the time of fracture and one-third were in institutions.

Estimation of mobility Mobility indoors was graded in the 1973 series of patients as follows: patients confined to bed or in a wheelchair, or requiring support by another individual, scored 0 points, walking frame 2 points, rollator, 3 points, quatrapped, 4 points, walking stick, 5 points and requiring no support 6 points (Ceder et al 1979). Mobility before fracture was assessed by information from the patients, relatives or from nursing home personnel. Mobility after fracture was assessed at 2 weeks and 3 months, postoperatively, by a specially appointed physiotherapist.

Fracture treatment and postoperative mobilization

There was a marked difference in treatment philosophy between the 1966 and the 1972-1973 series: the latter series were subjected to surgery aimed at early mobilization and the patients were barred from weight bearing postoperatively only if the mechanical fixation of the fracture was regarded as insufficient.

In the 1966 series cervical fractures were usually fixed with a Thornton nail; these patients had 11 weeks of bed rest followed by mobilization over a period of 4 weeks without weight bearing. The majority of patients over 70 years of age with displaced cervical fractures had a primary Moore hemi arthroplasty, weight bearing was then gradually started 2-3 weeks postoperatively. Impacted cervical fractures were usually not

operated upon; these patients had 11 weeks of 6 weeks of bed rest followed by weight bearing. Trochanteric fractures were fixed with a nail plate according to McLaughlin; the patients allowed weight bearing 6 weeks postoperatively.

In the 1972-1973 series cervical fractures were fixed with a spring loaded nail according to (1964) and hemi arthroplasty was used sparingly, for example because of a pub fracture, failure of reduction etc. The majority of the trochanteric fractures were fixed with a nail and plate according to McLaughlin; in the 1972-1973 series the fractures were fixed with Enders nails. In the 1972-1973 series patients were encouraged to bear full weight the day after operation, the only exceptions being cases where the mechanical fixation of the fracture was deemed insufficient.

Hospitalization time decreased from 44 days in 1966 to 27 days in 1972-1973. This decrease was mainly due to early discharge of patients to their own homes; this group had 50 days of hospitalization in 1966 and 24 days in 1972-1973 (Table 2).

RESULTS

The mortality rate during hospital stay was 9 per cent both in the 1966 and the 1972-1973 series. Of the surviving patients admitted from their own homes, 48 per cent returned directly home in 1966 and 61 per cent in 1972-1973 (Table 2).

The mobility score both before fracture and at follow up was better for patients from their own homes than for patients from nursing homes (Table 3). Of the patients who scored 4

* 2 Mean hospital days and discharge from
 * 2 of patients with hip fracture admitted
 * 2 their own homes in 1966 and 1972-1973

Targeted on pital o	1966		1972-1973	
	Patients (n)	Days (mean)	Patients (n)	Days (mean)
Home	45	50	141	24
Nursing	24	39	48	34
Institution	11	52	19	33
Other	16	47	20	55
Total	93	47	228	30
Discharged	9	25	19	16

ore before the fracture 107 out of 108 were
 itted from their own homes and 36 out of
 were from institutions. At 3 months
 operatively this score had been regained by
 f the 107 from their own homes and by only
 f the 36 from institutions. The difference
 highly significant ($P < 0.001$, Chi-square

he mobility score 2 weeks postoperatively
 ed an early and valid indicator of the
 -term prognosis for patients admitted
 i their own homes (Table 4). All but one
 a pre-fracture score of 4 points or more
 71 patients who had returned home at
 3 months follow-up had a 2-week score of
 2 to 4 points. The six patients who were
 arged to nursing homes had 0 points.
 31 patients who were discharged to less
 odial types of nursing care or rehabilitation
 a 2-week score of about 2 points.

DISCUSSION

The mean hospital stay for hip fractures was around 3-4 weeks during the 1970's in several countries in western Europe (Gallannaugh 1976, Dolk & Westerborn 1977, Karumo 1977, Ødegård & Unsgård 1978, Steen Jensen et al 1979, 1980). However, assessments of mean hospital days are unreliable because they are often merely an expression of the different possibilities available for aftercare (Dolk & Westerborn 1977).

The present investigation showed that the proportion of patients discharged to their own homes after hip fracture definitely did not decrease but rather increased in spite of a dramatically shortened hospital stay. Early mobilization and discharge of a patient with a hip fracture thus does not mean that the burden of care for these patients has been passed on to other institutions.

Comparing the rate of discharge to the patient's own home with the findings of other authors in countries with different health and social systems is both difficult and perplexing. Camblin (1974) and Smith & McLauchlan (1975) in Great Britain discharged between one-half to two-thirds of patients to their own homes but the mean hospital stay was up to 2 months. Ring (1963) and Pösgenfürst & Schnabl (1977) discharged half of their patients to their own homes following early

Table 3 Mean mobility score before fracture, and after osteosynthesis and mobilization, for surviving patients with hip fracture admitted in 1973 from their own homes or from institutions

Admitted from	Mean mobility score		
	Before fracture	2 weeks postop	3 months postop
Own home (n=108)	5.7 ± 0.1	3 ± 0.2	4.2 ± 0.2
Institution (n=48)	4.2 ± 0.4	0.9 ± 0.2	1.8 ± 0.4

Values—Mean ± Standard error of the mean

Table 4 Mean mobility score before fracture, and after osteosynthesis and mobilization, for surviving patients with hip fracture admitted in 1973 from their own homes and discharged to their own homes or to institutions

Discharged from hospital to	Mean mobility score		
	Before fracture	2 weeks postop	3 months postop
Own home (n = 71)	58 ± 01	37 ± 02	48 ± 01
Rehabilitation or other hospital unit (n = 24)	58 ± 01	18 ± 04	37 ± 04
Old people's home (n = 7)	57 ± 03	23 ± 08	31 ± 08
Nursing home (n = 6)	48 ± 10	0	03 ± 03

Values = Mean ± Standard error of the mean

postoperative weight-bearing. Ødegård & Unsgård (1978) reported the same rate of discharge to own home. On the other hand, Stewart (1955) did not allow weight-bearing for 3 months postoperatively and still had a discharge rate of 80 per cent after 6 weeks hospitalization, clearly Stewart's patients must have received more help at home than is readily available under today's social conditions. Steen Jensen et al (1979, 1980) had a discharge rate to own home of only 30 per cent after hospitalization for 3 weeks, because a large proportion of the patients had a period of institutionalized rehabilitation, before they returned home.

The distinction between patients coming from their own homes and those coming from institutions is clearly fundamental for any meaningful comparison of hospitalization following hip fracture. Thus, the decrease in postoperative hospitalization noted here in

patients admitted from institutions had or nothing to do with a change in attitude towards early mobilization. The hospitalization of this group of patients mainly due to the general acceptance of a rule that an institutionalized patient should not lose her bed on admission to it because of a fractured hip.

The application of an active rehabilitation programme for hip fracture patients requires that it be defined as early as possible. This is a problem only in patients who lived at home at the time of fracture, institutionalized patients can hardly ever be rehabilitated to non institutionalized living. For the purpose of making a good guess at a realistic rehabilitation goal, we have found the 2-month mobility score more useful than the assessment of the patient's prefracture status. Recording the mobility score early rather late, time is gained for improvement of the social environment to which the patient eventually returns. Patients returning home need increased domestic help (Ceder 1979). In fact, studies in progress (Ceder et al) suggest that in Sweden, at present, a realistic goal to discharge about 75 per cent of patients with a fractured hip directly to their own homes, another 10 per cent to be rehabilitated to home status after temporary institutionalization.

A higher incidence of institutionalized rehabilitation is probably unnecessary and may even be harmful. Steen Jensen et al (1979, 1980) reported a discharge rate to the patient's own home of only 30 per cent because the majority of the patients were rehabilitated in an institution. It was demonstrated that these latter patients did not attain better function than those who were rehabilitated at home.

The main obstacles to rehabilitation of elderly after hip fracture are often medical and/or social in nature—and less mechanical. However, early detection of mechanical failure of the fixation device is one of the positive results of early mobilization and weight-bearing, i.e. poor mechanical fit

discovered and corrected by means of any arthroplasty or other measures, shortening the rehabilitation time

In conclusion, this study has shown that hospitalization following hip fracture do cause correspondingly greater use of many institutional facilities. Early mobilization of a patient with a hip fracture does not mean that the burden of these has been passed on to other institutions. The mobility score 2 weeks after surgery seems to give a better indication of possibilities for early return home than one before the fracture. This makes it for the hospital staff to assess the need of care.

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MORTALITY AND LIFE EXPECTANCY AFTER FRACTURES

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Follow-up data for at least 4 years was collected for 675 patients treated for hip fractures in the period 1961-1970. Compared with a series from the same hospital for the years 1948-1957 the number of patients had more than doubled and a higher hospital mortality was encountered, but the 4-year survival rate was unchanged. The mortality after hip fracture was found to be related to the age and sex of the patient and to the nature and number of associated diseases. The mortality rate was found to be high in the first 2 months following the fracture, but patients surviving the second month showed no excess mortality during the following 4 years, having the same life expectancy as the general population.

Key words: femoral neck fractures, hip fractures, long-term survival, mortality

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ous reports have been published concerning mortality after hip fractures, but only a few papers have dealt with the long-term survival.

Skelsen & Langholm (1964) studied mortality, over a 4-year period, after hip fractures in 277 patients treated at Haugesund Hospital between 1948 and 1957. As the number of patients with hip fractures increased in recent years, we have studied a comparative series of patients from the same hospital for the period 1961-1970, comparing the mortality rate with that in the general population.

During the period 1961-1970, 667 patients with 680 fresh hip fractures (viz. fractures of the trochanteric region and the femoral neck) were treated at Haugesund Hospital. Follow-up data until death or for a minimum of 4 years was collected from registrars' offices and the Central Bureau of Statistics, Norway. Five patients (0.7 per cent) were lost to follow-up. Thirteen patients sustained two hip fractures during the period, and these counted twice in the series. The total number of patients followed up thus amounted to 675. Five hundred fractures (74 per cent) were encountered in women. Femoral neck fractures occurred in 70 per cent of the cases (476/675) and trochanteric fractures in 30 per cent (199/675) (Table 1). Twenty-seven per cent of the femoral neck fractures (123/476) were impacted or showed no displacement.

PATIENTS AND METHODS

Haugesund Hospital is located in the southern part of Norway and served, until 1970, a community of approximately 100,000 people, two thirds of whom were living in a rural area.

Age. The arithmetic mean age of all female patients was 71.5 years, of all male patients 74.7 years, and of both sexes 73.9 years (17-99 years). Figure 1 shows the age distribution. In patients below the age of 50 years, males dominated (54 per cent), but in the older age groups the predominance of females was marked (75 per cent).

Table 1 Number of hip fracture patients admitted to Haugesund Hospital in the years 1961-1970 followed up for at least 4 years, divided according to sex and fracture type

Patients	Number of fractures		Total
	Femoral neck	Trochanteric	
Female	366	134	500
Male	110	65	175
Total	476	199	675

Fracture type Trochanteric fractures were overall more common in men (37 per cent) than in women (27 per cent) ($P < 0.001$). The number of trochanteric fractures decreased with age in males, but increased with age in females. In patients above the age of 70 years the percentage of trochanteric fractures was 30 for both sexes.

Treatment Dislocated fractures were treated non-operatively with traction for an average of 45 days. Femoral neck fractures were treated by internal fixation with a Smith-Petersen-Johansson nail. In 3 per cent of the patients (12/476), however, a primary arthroplasty was performed, and 26 per cent of the patients (142/476) were treated by non-operative means. In trochanteric

fractures internal fixation was performed with a McLaughlin plate in 71 per cent of the (142/199) while 29 per cent (57/199) were treated non-operatively. Early postoperative mobilization was favoured and anticoagulant prophylaxis seldom used. Prophylactic antibiotics were administered.

Associated diseases Based on the nature of associated diseases discovered during the operative evaluation, the patients were retrospectively into three groups according to Fitts et al. (1959). Group I included patients with mild or no associated pathological process, Group II included patients with moderately associated disease and Group III included patients with severe associated disease, e.g. myocardial infarction, renal failure, compensated congestive heart failure, metastatic cancer. We recorded the number of pathological conditions (groups I, II, III) found in each patient.

For the statistical analysis the Fisher's non-parametrical test was applied in all tables and the chi square test in 2×2 tables. Using the procedure of Schor (Fitts et al. 1959) life tables were calculated for the patients according to information given by the Central Bureau of Statistics (1972) for the years 1961-1970 for a series with comparable sex distribution. Life tables based on the mortality of the patients with hip fractures were also calculated and the proportion of patients surviving various time periods was plotted for two groups. The difference between the "observed" in the patients and that "expected" in the general population gives a direct measure of the contribution of the specific condition under investigation to mortality. The point at which the two curves become parallel is the point at which the patients die at the same rate as the population (Gordon 1971).

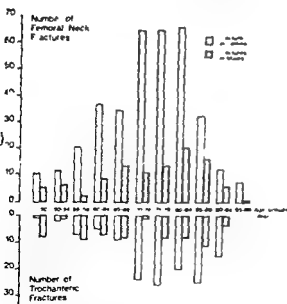


Figure 1 Distribution of 500 women and 175 men with hip fractures as regards age and fracture type

ULTS

ospital mortality was calculated to be per cent (94/675). The average hospitalization time was 34.6 days (1-203).

Most deaths were caused by pneumonia (29/94), cardiac failure) and cerebral vascular accidents). In 7 per cent of the patients (7/94) pulmonary embolism was suspected. There was no significant difference in death rate between male patients with intertrochanteric fractures and male patients with intracapsular neck fractures or between female patients with trochanteric fractures and female patients with femoral neck fractures, 1 month, 2 months, 6 months and 4 years after injury. The two fracture types were therefore considered together in the following statistical analysis.

One-month mortality within 1 month was 17.1 per cent (30/175) in men and 9.8 per cent (10/102) in women ($P < 0.01$). This mortality was related to age, ranging from 2 per cent in men (2/96) and men (1/50) less than 65 years of age to 21 per cent in women (20/94) and 38 per cent in men (15/39) more than 84 years of age. A similar age-related mortality was found in the second month after injury, i.e. no deaths

in patients less than 65 years, but 10 per cent of the women and 17 per cent of the men over 84 years died during the second month. Of patients 75 years old or more 78 per cent of the men (70/90) and 61 per cent of the women (164/271) died during the first 4 years after fracture. The higher male mortality within the first month appeared to be the main factor causing the lower long-term survival in men.

The mortality during the first month was about 15 times and during the second month about 7 times the expected mortality of a sample from the Norwegian population of the same size and similar age and sex distribution (Table 2). Thereafter the death rates corresponded to those of the general population (Figure 2). Thus the excess mortality was essentially attributable to the deaths during the first 2 months after fracture.

Table 3 shows the number of severe and moderately severe diseases in the patients. The probability of dying within the first 6 months after hip fracture increased proportionally with the number of associated diseases described on admission (Figure 3). (The group with four or more additional diagnoses consisted of 16 patients and was too small for reliable statistical calculations.) Similarly, there was a significantly higher

2 Life tables for the years 1966-1970 (Norway's Official Statistics/Central Bureau of Statistics of Norway 1972)

Age (years)	Expectation of life (Average number of years of life remaining)		Mortality (per 1000)	
	Males	Females	Males	Females
71-79	10.9	16.8	15.6	12.0
70-79	25.3	29.4	6.0	3.1
69-79	21.1	24.9	9.8	4.7
68-79	17.3	20.6	15.8	7.9
67-79	13.8	16.5	26.6	13.8
66-79	10.8	12.8	42.3	24.5
65-79	8.3	9.6	64.3	44.7
64-79	6.1	6.9	99.8	77.5
63-79	4.4	4.9	151.8	132.9
62-79	3.1	3.5	228.9	200.7
61-79	2.2	2.5	320.0	287.9
60-79	1.4	1.8	450.0	360.6

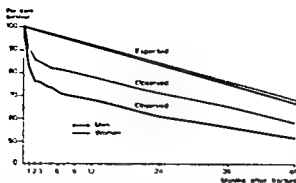


Figure 2 Observed survival rates in men and women with hip fractures compared with expected survival rates of Norwegian people of corresponding age and sex

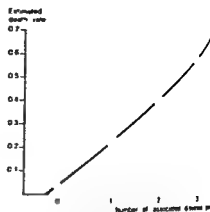


Figure 3 Estimated death rate of patients first 6 months after hip fracture as a function of associated diseases

proportion of severe associated diseases in patients dying during the first 6 months than in patients surviving at least 6 months ($P < 0.001$) (Table 4).

The data from the present series was compared with the series of Mikkelsen & Longholm (1964) from 1948-1957. The ratios

men/women and trochanteric femoral neck fractures were the same. The proportion of male and female patients over 75 years of age was significantly higher in 1961-1970 than in 1948-1957 ($P < 0.001$). The case mortality in 1961-1970 was 13.9 per

Table 3 Mortality and survival in patients with hip fractures in relation to number of associated diseases per patient

Number of patients	Number of associated diseases per patient					Total
	0	1	2	3	≥ 4	
Patients dying within 6 months	8	43	45	37	9	142
Patients surviving 6 months or more	289	148	67	22	7	533
Total	297	191	112	59	16	675

Table 4 Mortality and survival in patients with hip fractures in relation to severity of associated diseases

Number of patients	Severe associated disease	Moderately severe or no associated disease	Total
Patients dying within 6 months	24	118	142
Patients surviving 6 months or more	13	520	533
Total	37	638	675

5), significantly higher than the 4 per 3/277) in 1948-1957 ($P < 0.001$), the mean length of hospital stay stated by Mikkelsen & Langholm (1964) for the year survival of male as well as female over 75 years was similar in the two

DISCUSSION

At Haugesund Hospital was the only centre for the treatment of hip fractures in a defined geographical area with a stable population and was thus suitable for epidemiological investigations.

Comparing the present material with Mikkelsen & Langholm (1964) from 1957, we found two marked differences. The number of cases had more than doubled and there was a higher hospital mortality in 1970.

The increase in the number of fractures is thought to be explained only by the increase in the mean age of the population. Alffram (1964) found the annual number of fracture increased by a factor of three over 13 years in Malmö, whereas the total population increased by less than 20 per cent. Falch & Selvik (1978) reported a similar increase in the incidence in Oslo, which they related to an increase in the incidence of metabolic disease.

The hospital mortality in Haugesund in 1948-1957 was low, so low that a decrease was not likely, but we did not detect the marked increase in the period 1958-1970. The hospital mortality, however, is highly dependent on the length of hospital stay, and comparison of statistics from different hospitals, or from different periods at the same hospital must be made with some caution (Alffram 1964, Gordon 1971, Mikkelsen et al. 1956), and especially compared with studies where the hospitalization rate is not reported (e.g. Beals 1972, Clark & Wright 1966, Lindholm et al. 1971, Mikkelsen & Shelby 1964, Mikkelsen & Selvik 1964, Sweet et al. 1967, Weedon et al. 1970, Wong 1969).

To avoid the variables of hospital mortality, some authors define a "primary mortality", i.e. the death rate during a period in which the hip fracture together with associated diseases must be regarded as the decisive mortality factor (Fitts et al. 1959, Riska 1970). Riska (1970) felt that the limit for this "primary mortality" was 30 days after injury or operation, and Barnes et al. (1976) used mortality at 1 month in their prospective, multicentre study.

Mortality at 1 month may be practical in comparing different series, but the 30-day limit seems arbitrarily chosen and does not reflect the "primary mortality" as defined above by Riska (1970). With the use of life tables Fitts et al. (1959), Hansen & Neidhardt (1970), Niemann & Mankin (1968) and Colbert & O'Murcheartaigh (1976) showed the excess mortality after hip fractures to be essentially attributable to deaths in the first 6 months. Miller (1978) found the excess mortality to be most apparent in the first 4 months following injury, but that it persisted for at least 8 months. Gordon (1971) noted that the period of greatest mortality was within the first 12 weeks, and Alffram (1964) in a more detailed study pointed out that patients surviving the first 3 months had the same life expectancy as the general population. Evans (1979) found, in addition to an early period of high risk of death, a secondary rise occurring after 4 to 6 weeks.

In analysing the death rates during the first year in our material, we found the death rate during the first month to be approximately 15 times and during the second month about 7 times the expected death rate of a matched sample of the general population. Patients surviving the 2 first months showed no significant excess mortality during the following 4 years, indicating the same survival rate as the general population. The death rate at 2 months might therefore give a more correct "primary mortality", as defined above, than mortality at 1 month.

Reno & Burlington (1958) stated that no single factor influences the prognosis in any given case as markedly as the patient's age

As in other series (Alffram 1964, Beals 1972, Colbert & O'Muircheartaigh 1976, Gordon 1971, Katz et al 1967, Miller 1978) we found a close correlation between mortality and age, and our age-related death rates at 1 month were similar to those of Riska (1970) and Barnes et al (1976). Mikkelsen & Langholm (1964) demonstrated excess mortality in hip fracture patients even in the age group 60-64 years and like them we found excess mortality, particularly in patients over 75 years of age. In the present material there was a marked shift towards older patients. The proportion of patients over 75 years was significantly higher than in 1948-1957, a fact that also to some degree might influence the higher hospital mortality in our series.

In this study there was a significantly higher death rate in men than women during the first 2 months after fracture. A higher male mortality has been demonstrated in several surveys (Barnes et al 1976, Beals 1972, Colbert & O'Muircheartaigh 1976, Gordon 1971, Mikkelsen & Langholm 1964, Miller 1978), while sex differences were not present (Alffram 1964, Evans 1979) or not stressed (Fitts et al 1959, Katz et al 1967, Lindholm et al 1971) by other authors.

There is a strong relationship between mortality after hip fractures and associated diseases in the patients (Alffram 1964, Fitts et al 1959, Miller 1978, Schenk et al 1956), in our series shown to be partly dependent on the nature of the disease and partly dependent on the number of significant diseases in each patient.

A higher mortality has been reported in patients with trochanteric fractures (Beals 1972, Colbert & O'Muircheartaigh 1976, Fitts et al 1959). Weedon et al (1957) noted the trochanteric cases to carry a higher death rate because the patients were older, and after correction for differences in the age distribution of the patients Alffram (1964) found the mortality to be unrelated to the main type of fracture. This was in accordance with our findings and others have also been unable to confirm any influence of the type of fracture on survival (Gordon 1971, Manpel et al 1961,

Meyn et al 1977, Mikkelsen & 1964, Sweet et al 1967).

A comparison of death rates patients grouped according to treatment was not attempted in the agreement with some authors (Cambis Lindholm et al 1971, Riska 1970, Sweet 1967), but not with others (Alffram Schenk et al 1956, Shafian et al 1967) noted a markedly higher death rate during the first months in patients treated operatively compared with operated patients. However, after analysing age, associated diseases in these two groups became apparent that the operated patients reflected the selected patients rather than the particular procedure. Other factors concerning treatment may interfere with primary mortality but not the selection. It can therefore be drawn in a retrospective way (Gordon 1971, Miller 1978).

The factors influencing mortality set out in this survey should be considered in choosing the method of treatment for each patient individually. It is recognised that operative methods permitting mobilization and weight bearing are used in geriatric patients (Attenborough & Devas 1974). Several reports on procedures preserving the femoral head allowing unrestricted rehabilitation have been made (Abrams & Stevens 1964, Alffram 1971, Garden 1961, Graham 1968, Lindholm 1969, Nieminen 1975). Mikkelsen & Langholm (1964) stated that in patients older than 70 years prosthetic replacement of the femoral head in fresh femoral neck fractures might be a suitable substitute for nailing as the first operation because the majority would be old enough to experience any of the known complications. Other authors support a still lower age limit for arthroplasty (Carr 1974, Hansen & Neidhardt 1970, Muckle & Ramstad 1966, Simons & Limborsch 1969). Our study indicates that patients surviving the first 2 months have approximately the same life expectancy as the general population which in 1970 was 11 years for

1 man and 13 years for a woman of the age. When choosing the treatment, the general condition of the patient may be a better criterion than the patient's age (Fitts et al 1959, Lindholm et al 1971), and if a prosthetic replacement is used in a patient with a relatively long life expectancy, careful selection of type and of prosthesis is essential (Dahl & En 1976).

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ANTERIOR DISPLACEMENT OF THE TIBIAL TUBEROSITY IN THE TREATMENT OF CHONDROMALACIA PATELLAE

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Anterior displacement of the tibial tuberosity combined with shaving of the diseased cartilage was used as treatment for chondromalacia patellae in 32 knees in 28 consecutive patients and in one patient with chondromalacia femoris. The patients were aged 17 to 57 years. One patient had earlier sustained a serious injury to the ligaments of the knee, resulting in instability. All patients except one were unfit for work before the operation. Postoperative extra-articular wound infection was noted in two knees and venous thrombosis occurred in three legs. The postoperative observation period varied from 8 months to 2 years and 10 months. In one knee the anterior displacement of the tibial tuberosity was not maintained. In lateral radiographs the anterior displacement of the tibial tuberosity in the other knees varied from 10 to 23 mm. The relief from pain obtained by the operative treatment was estimated as good in all knees except three, which were unchanged. All patients became fit for work and/or sport.

Key words: cartilage, articular, chondromalacia patellae, knee joint, patella

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Chondromalacia patellae usually affects young individuals, reducing their capacity for heavy work because of pain on exertion. Pain markedly increases the mechanical stress acting on the articular surfaces in the femoral joint, and the patients' symptoms seem to be related to the increased strain on the diseased articular surface (Maquet 1976).

Recent studies indicate that anterior displacement of the tuberosity of the tibia – reducing distal anchorage of the patellar tendon – considerably reduces the mechanical stress on the patellofemoral joint and so relieves pain in chondromalacia patellae (Maquet 1963, 1976, Bandi 1972). In this study we present our findings after using this method to treat 29 consecutive patients with chondromalacia patellae.

PATIENTS AND METHODS

Patients. This prospective investigation comprised 29 inpatients (33 knees) admitted from March 1976 to March 1978. There were 11 women and 17 men aged 17 to 57 years (median 30 years), 2 women and 2 men (5 knees) were below 20 years of age. No two had the same occupation. On admission all the patients were unfit for work except one, and he was unable to take part in the national skiing competitions because of bilateral chondromalacia patellae. Previous sporting activities, traumas and knee operations are listed in Table 1.

Symptoms, signs and selection of patients. The duration of the symptoms varied from 6 months to 4 years (median 3 years). The patients' main complaint was pain on exertion located ventrally

Table 1 Preoperative data in 29 patients (33 knees)

	No of patients (p) or knees (k)
Participated in sport	11 p
Patellar trauma	17 p
Knee ligament injuries	1 k*
Previous knee operations	
—meniscectomy	6 k
—shaving of patellar cartilage	1 k
—other	1 k

* Unstable knee

Muscle wasting in the thigh was noted in 18 knees and intra-articular fluid in 15 knees. The affected patella was always tender when its deep surface was rubbed against the underlying femoral condyles and patellar grating was felt when the knees were actively extended. Six patients were bilaterally affected, but only four of the six were advised to have a bilateral operation.

Only patients unfit for work and/or competitive sports were given operative treatment and included in this study. No systematic preoperative treatment was given before admission to this hospital.

X-rays Ordinary anteroposterior and lateral radiographs were taken of both knees in all patients. Tangential views of the patellofemoral joint were also taken. In lateral preoperative radiographs the patellar height ratio was calculated by dividing the distance from the lower end of the articular surface of the patella perpendicular to the tangent of the tibial plateau by the length of the articular surface of the patella (Blackburne & Peel 1977). There were no significant pathological findings.

Operative procedure The knee joint was usually opened by the different surgeons through a lateral parapatellar incision in a bloodless field. When a medial meniscal lesion was suspected a medial incision was used. The macroscopic pathological changes in the cartilage were graded according to severity as outlined by Bandi (1972). All diseased cartilage was shaved off the patella and any affected part of the femoral condyles. Deranged menisci and loose bodies were removed. The joint cavity was then closed, the skin incision was enlarged distally and the tibial tuberosity was displaced towards the front (Bandi 1972). The displaced tuberosity was kept in place by a triangular bone block taken from the anterior iliac crest. The block was fastened by a



Figure 1 Lateral radiograph of right knee anterior displacement of the tibial tuberosity maintained by a triangular bone block screw.

4 cm long slender AO screw (Figure 1). Full compression bandage was applied from the above the knee.

Postoperative regimen and follow-up After operation the patients were kept in bed for 1 week with the operated knee semiflexed and elevated on a splint. Exercises using the quadriceps muscle were encouraged before and after the operation. Patients were allowed partial weight-bearing out of bed on crutches. Full weight-bearing was allowed until X-rays showed that the displaced tibial tuberosity had healed (12 months after the operation). The screw was removed. In the 13 patients most recently operated on the compression bandage was removed in the afternoon of the day of operation. The leg was placed on a pillow and the patient was allowed to move freely, to reduce the risk of postoperative thrombosis. No prophylactic antibiotic or anticoagulants were given.

Only patients with a postoperative observation period of at least 8 months were included in the study, the maximum observation period being 108 months (median 22 months).

2 Postoperative findings in 33 knees

	No of knees
malacia	
only	22
only	1
and femur	9
, femur and tibia	1
	33
menisci	3
odies	2
d synovitis	4
instability	1

Severity of chondromalacia in 33 knees

	No of knees
I	12
II	8
III	10
IV (degeneration)	3

ding to Bands (1977)

LTS

eration, the diagnosis chondromalacia was verified in all knees but one, in the lesion of the articular cartilage was ed to the femoral part of the femoral joint. Since the signs, oms and results of treatment in this ular patient did not differ from the he has been included in the material. Postoperative findings are listed in Tables

one patient the bone graft was gradually ed into the metaphysis of the tibia ; to faulty operative technique and the ed anterior displacement of the tibial osity was therefore not maintained, but patient became symptom-free. In the knees the anterior displacement of the tuberosity in lateral radiographs varied 10 to 23 mm (median 15 mm) (Figure 1 follow-up no joint effusion was noted ny of the operated knees. All were ed from pain on exertion and at rest

except three, which were unchanged. All patients became fit for work and/or sport, but three patients changed their jobs.

Postoperative complications Postoperative extra-articular wound infection by staphylococci was noted in two knees. The infection subsided after surgical intervention and treatment with parenteral antibiotics. Three patients contracted a deep venous leg thrombosis verified by phlebography. Treatment by intravenous streptokinase combined with warfarin sodium was complicated in one of these patients by bleeding from the donor site on the iliac crest, which necessitated surgical intervention. Delayed but uneventful recovery then followed.

DISCUSSION

Several methods of operative treatment for chondromalacia patellae have been used, from simple ones such as shaving of the articular cartilage of the patella to radical surgery such as patellectomy (Outerbridge & Dunlop 1975).

Wiles et al (1956) performed patellectomy in 15 (33 per cent) and patellar shaving in 31 (67 per cent) knees operated on for chondromalacia patellae. Patellectomy later became necessary in an additional six of these cases (Wiles et al. 1960). Thus, patellectomy was done in 21 (46 per cent) out of the total of 46 knees. Patellar shaving gave good long

of 140 knees operated on for chondromalacia patellae. Satisfactory results were obtained in 77 and 25 per cent of these cases, respectively. Therefore, according to Bentley (1978), shaving of the patella remains an unsatisfactory procedure. This is especially the case in patients under the age of 20 years (Wiles et al. 1960, Bentley 1978).

Although neither Wiles et al (1956) nor

Bentley (1978) described their methods of patient selection for either operative method, simple techniques like patellar shaving obviously do not always give relief from pain. In contrast, when shaving of diseased cartilage was combined with anterior displacement of the tibial tuberosity as above, we were able to obtain pain relief in 30 out of 33 knees operated on, regardless of the patients' age, sex, or occupation, and regardless of the patellar height and the extent of the pathological changes of the articular cartilage in the knee. If one patient with a post-traumatic unstable knee and incipient arthrosis in the tibiofemoral as well as in the patellofemoral joints is excluded we obtained satisfactory results in 30 (94 per cent) out of 32 knees. Since shaving of the patella alone appears to give good results in 25 (Bentley 1978) to 71 per cent (Wiles et al 1960) of selected cases, ventral displacement of the tibial tuberosity would seem to be an essential addition to the treatment.

The frequency of postoperative complications observed here — 6 (18 per cent) in 33 operations — seems high, but no permanent sequelae were observed. We believe that the complications reported above can be avoided by improved surgical techniques and that the risk of postoperative leg thrombosis can be lessened by avoiding a compression bandage on the knee and by early mobilization of the patient.

The short term results have been encouraging and anterior displacement of the tibial

tuberosity seems to be a promising operative method for treatment of chondromalacia patellae. The complications encountered, however, suggest that the patients should be carefully selected and only patients who work and/or competitive sport should be advised to have such an operation.

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MICROVASCULAR OSTEOCUTANEOUS GROIN FLAP IN THE TREATMENT OF AN UNUNITED TIBIAL FRACTURE WITH CHRONIC OSTEITIS

A Case Report

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A 37-year-old man with an ununited tibial fracture combined with a significant skin defect underwent a microvascular transfer of an island osteocutaneous flap of groin skin and iliac crest bone. The bone component of the flap was shown to be a living transplant by the observation of brisk capillary flow in the bone marrow when the flap was perfused on its vascular stalk.

Key words: fracture, microvascular transfer, non-union, osteitis, osteocutaneous groin flap, tibia

Accepted 7 x 79

Treatment of established non-union of tibial fractures is a complex problem often requiring several surgical interventions, including debridement of soft tissue and necrotic bone, irrigation, drainage and repeated bone grafting. Extensive repeated bone grafting after previous surgical attempts, and necrotic bone and draining fistulas make the skin coverage troublesome. The leg region becomes progressively less functional. Antibiotic therapy is of dubious value and the bed for bone grafting undisturbed.

The introduction of microsurgery and free microvascularized osteocutaneous flaps offers a solution to the problem of both the skin and bone defects, and at the same time restores the circulation in the tissues to promote fracture healing.

Few cases have been reported where this technique has been used in the treatment of ununited infected fractures of the lower leg. The purpose of this case report is to present this method which is comparatively new and so far has not been employed elsewhere in Scandinavia.

CASE HISTORY

A 35-year-old man with a history of alcohol abuse sustained a closed oblique fracture of the distal tibial shaft in February 1976. Open reduction was carried out on the third day and the fracture was anatomically reduced with two circumferential wires. The postoperative period was uneventful and healing progressed clinically to such an extent that weight-bearing without plaster was allowed after 4 months. The patient was then lost to follow-up.

He returned in August 1977 with refracture following a fall whilst intoxicated. (It was then clear that radiological union of the primary injury had never taken place.) The refracture was technically compound because the overlying skin was damaged over an area of 3×4 cm. A second operation was performed using a sliding bone graft and cancellous bone chips from the right iliac crest. The damaged skin was excised and skin closure facilitated by means of two relaxation incisions on either side of the wound. A deep infection supervened postoperatively and despite repeated surgical procedures, the bone did not heal and the infection did not resolve. By November 1978, two and a half years after the original injury, the patient had established non-union, extensive osteitis and a skin defect 3×4 cm in size (Figures 1a, b). Standard methods

OPERATIVE METHOD

Smoking was forbidden for 1 week and 3 weeks postoperatively. Clinical and Doppler ultrasonic probing showed anterior and posterior tibial arteries and Allen's test demonstrated that the system could adequately nourish the foot.

The operation was performed by operating simultaneously one team a flap and the other team dissecting the region. In the recipient site the 5×10 cm was excised as the considerable sclerotic bone from the creating a substantial bone defect. The vessels were the anterior tibial artery and venae comitantes. Projectile artery confirmed the ability of this flap after transfer.

In the donor region an oval 7×22 cm was prepared as the superficial circumflex iliac and inferior epigastric branches of the (which in this case arose from a and drained by two superficial circumflex veins, which had united into a common saphenous vein. The flap was with a 2×7 cm piece of iliac crest 1 cm extension of iliac periosteum, by careful preservation of soft tissue connections between skin and iliac crest (Figure 3b). When the flap was completed and the composite as an island based on its vascular stalk, all areas of soft tissue as well as cancellous bone bleeding briskly thus confirming the deep flap vascularity.

The island flap was separated from the vessels in the groin and transferred to recipient region. The iliac bone block was slotted into a groove prepared in the tibial anteriorly (Figures 2b, 3c), further packed cancellous bone chips, and the flap periosteum wrapped around. No bone fixation was used. The skin edges were sutured (Figure 2b). Vascular anastomoses performed end to end 10-0 monofilament nylon under the operating microscope. The venous anastomosis was first between the flap vein and the most proximal venae comitantes. Both veins measured 2 cm external diameter and 13 sutures were used. Arterial anastomosis was performed next between the anterior tibial artery measuring 3 mm diameter and the 1.4 mm flap artery by 12 sutures. Upon release of the arterial anastomosis, immediate flap revascularization occurred. Ischaemia time was $3\frac{1}{2}$ hours. Total operative time was $8\frac{1}{2}$ hours.

A plaster slab was applied to the leg post-



Figure 1 Preoperative condition with (a) draining fistula, skin defect, extensive scarring and (b) established non union

having failed this case was judged to be suitable for a microvascular free osteocutaneous groin flap so as to provide the necessary vascularized bone graft and skin cover and at the same time introduce a new blood supply into the poorly nourished scarred region.



Immediate postoperative result (a) Skin sutured in place and (b) the iliac bone block into a groove in the tibia

was required and exposure of the flap was in order to observe circulation. The wound was closed by direct suture and drainage.

W-UP

Postoperative vascular complications were avoided. The skin margins healed well except for a 1 cm long wound on the medial side, which healed over several weeks. Immediate postoperative radiographs showed a good position of the bone (Figure 2b). A light cast was applied on the 10th day and the patient discharged at 10 weeks, non-weight-bearing.

At 15 weeks the fracture showed bony and clinical union and the patient permitted full weight-bearing without aid (Figures 4a, b and c).

Scanning using Technetium 99m Diphosphonate showed no active

circulation in the graft on the first postoperative day but from the first week postoperatively active uptake of the isotope was demonstrated.

The donor site healed rapidly and gave no problems. There was anaesthesia in the lateral thigh, corresponding to the distribution of the lateral cutaneous nerve, but this is gradually normalizing.

DISCUSSION

The case reported illustrates the use of a microvascular osteocutaneous flap as an advanced technique for solving the complex problem of a combined bone and skin defect in the lower limb (in this case established non-union of the tibia with an overlying skin deficiency). Repeated bone grafting had failed and amputation was seriously considered.

The method described, whilst comparatively new, has been reported by others (Taylor & Watson 1978, Morrison et al 1978, Weiland & Daniel 1979). The principle involves the transfer of free living iliac crest bone together with a composite of groin skin nourished by the superficial circumflex iliac artery. This artery which primarily supplies skin, ramifies also to iliac periosteum through branches preserved in the areolar tissue between skin and iliac crest and via the musculature attached to the surfaces of the iliac bone. The bone therefore remains as a "living" transplant, not only because of its *periosteal circulation* but also through tiny nutrient branches which pass from the periosteum through to the medulla. Such bone nutrition was demonstrated in this case by the brisk bleeding from the cancellous bone seen when the flap was isolated as an island. Similar observations have been reported by Taylor & Watson (1978). Furthermore, India ink injection studies in human cadavers by the same authors and barium sulphate injection studies (Fogdestam 1977, unpublished work), confirm the ability of the superficial circumflex artery to supply iliac crest bone.

The series does not include patients under 15 years of age. Also excluded were patients with epiphyseal separations, direct fractures and isolated ligamentous injuries, i.e. all supination-eversion injuries of stage 1 and some of the stage 1 supination-adduction, pronation-adduction and pronation-eversion injuries.

The following nomenclature is used: S = supination or supination-adduction fractures, SE = supination-eversion or supination-outward rotation fractures, PE = pronation-eversion or pronation-outward rotation fractures, P = pronation or pronation-adduction fractures and PD = pronation-dorsiflexion fractures. The figures following the type designation indicate the stage division.

Osteosynthesis and suture of ligaments were performed in 210 of the ankle fractures. During the period of the survey, the treatment principle was on the whole to carry out primary osteosynthesis on displaced fractures of all patients under the age of 50 years and on some of the elderly patients with serious fractures. The survey is retrospective, but owing to the department's special interest in these injuries very thorough case records have been kept and the information available concerning clinical and intraoperative findings is therefore sufficient. All fractures have been X-rayed in frontal, lateral and oblique projections.

RESULTS

The causative factors are shown in Table 1. More than half of the injuries were caused by slipping or falling on level ground. The series involves 263 men and 224 women. The age distribution is shown in Figure 1. The mean age is 44 years. In all the age groups over 40 years women predominate.

The distribution of the entire material into types and stages according to Lauge Hansen

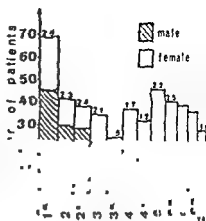


Figure 1 The distribution of the 488 fractures according to age and sex of the patients. Figures on top of the columns indicate the number of operatively treated fractures.

(1942) appears in Table 2. The classification is based on clinical, roentgenological and intraoperative findings. Only 12 per cent of the material cannot be fitted into this system.

In the following the stages of the individual fracture types will be described partly on the basis of roentgenological findings and partly on the basis of intraoperative findings.

Supination-eversion fractures

SE fractures made up 57.4 per cent (280/488) of all the ankle fractures. The distribution and the associated injuries are shown in Figure 2.

Stage 1 injuries in the anterior part of the tibiofibular syndesmosis corresponding to the anterior tibiofibular ligament (ATFL).

Isolated rupture of the ATFL.

Table 1 Causative factors in 488 ankle fractures

Sports injuries	37	11.5 per cent
Traffic accidents	63	13.0 per cent
Slipping or fall on level ground	281	57.6 per cent
Fall from a height	53	10.9 per cent
Other and unknown causes	34	7.0 per cent
	488	100.0

Table 2 Distribution of 488 ankle fractures into type and stage according to the patho-genetic classification of
N Lauge Hansen

SE fractures 280 57.4 per cent		P/PE fractures 102 20.9 per cent			S fractures 98 20.1 per cent			Other fractures 1.2 per cent	
stage	no	per cent	no	oper	stage	no	per cent	no	oper
SE 2	162	58.0	46	45.9	15	S 1	79	80.6	2
SE 3	11	4.0	7	17.6	6	S 2	19	19.4	7
SE 4	87	66	8	7.8	4	PD fractures 2 0.4 per cent			2
SE 4 (lux)	18	37.3	16	18.6	18	PD 1	1	—	1
SE 5	2	0.7	2	10.1	7	PD 2	1	—	1
								Isolated post tibial margin	4
								Atypical fractures	2

SE - fractures

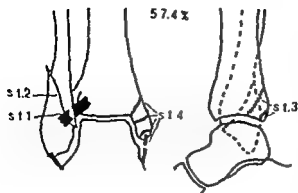


Figure 2. The stage division of supination-external rotation (SE) fractures according to Lauge Hansen.

included in this material. In connection with osteosynthesis of the lateral malleolus the anterior part of the syndesmosis was explored in 141 ankles. The injuries to the ATFL are shown in Figure 3. A further 4 per cent (6/141) had an incomplete rupture of the ATFL.

Although X-rays were taken in oblique projection, it was difficult roentgenologically to diagnose the avulsion of bone fragments at

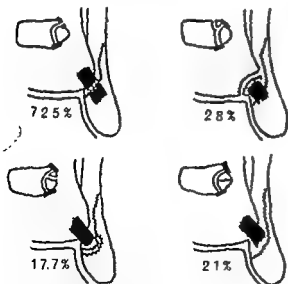


Figure 3. Stage 1 SE fractures. Operative findings of the injuries to the ATFL in 141 fractures; a further 4.2 per cent had incomplete rupture of the ATFL.

the insertion of the ATFL. Of the found at operation 10 have avulsed fragment, only in 10 could demonstrated radiologically.

In three cases the ATFL was found intact at operation. In these the fracture was described as running the fibular insertion of the ATFL.

Stage 2: Oblique spiral fracture of the malleolus running from the anterior in a dorso-proximal direction and including stage 1 injury (Figure 4)

SE 2 fractures made up 58.0 (162/280) of all SE fractures. The fracture can be more or less vertical at a variable distance from the tibiofibular space, as shown in Figure 5. The "high" fractures in the area "d" are



Figure 4. SE 2 fracture. Typical oblique spiral fracture of the lateral malleolus (oblique projection).

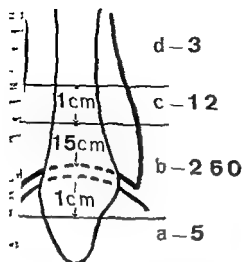


Figure 5 Stage 2 SE fractures The location of distal end of the fracture of the fibula in relation to the tibio-talar joint in 280 cases

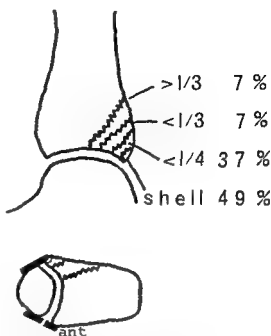


Figure 6 Stage 3 SE fractures Roentgenological classification of the injuries to the posterior tibial margin in 83 stages 3, 4 and 5 fractures

stage 2, one stage 3 and one stage 4. As a rule only a slight instability of the ligament is present because only the ligament is ruptured. Still in nine cases marked instability was found. This occurred in one stage 2 fracture and in eight stage 4 fractures. Of these fractures were located in area

3. Fracture of the posterior tibial margin including stages 1 and 2 (Figure 6)

3 fractures made up 4.0 per cent (80) of all SE fractures. Only in 14 per cent of the cases did the posterior fragments lie more than 25 per cent of the joint surface.

It is not necessary to have a fracture of the posterior margin before the injury advances to stage 4 fracture. Among 107 stage 4 and 5 fractures 32.7 per cent (35/107) did not have any roentgenological fracture of the posterior tibial margin.

4. Fracture of the medial malleolus or fracture of the deltoid ligament including stages 1, 2 and perhaps stage 3.

SE 4 fractures made up 37.3 per cent (105/280) of all SE fractures. Seventy five out of a total of 107 stage 4 and 5 fractures were treated surgically. If during the acute clinical examination tenderness, swelling and discoloration were present over the deltoid ligament and the X ray revealed no fracture of the medial malleolus then the ligament was considered injured. The frequency of the various injuries is shown in Figure 7. Fourteen per cent (15/107) of the fractures of the medial malleolus were found to have an oblique ($> 30^\circ$) direction.

Among women fractures in the medial malleolus were found in 63 per cent (37/59) whereas among men only 35 per cent (17/48) sustained this fracture.

Stage 5. Spiral fracture of the distal part of the tibia including stages 1, 2, 3 and perhaps stage 4.

This fracture was only found in 0.7 per cent (2/280) of all SE fractures (Figure 8).

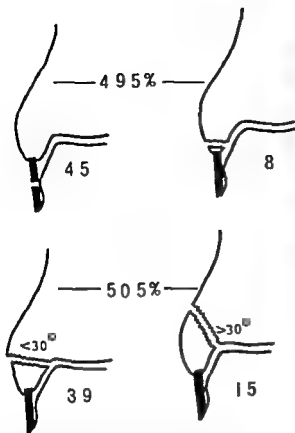


Figure 7 Stage 4 SE fractures Roentgenological, clinical and operative classification of the injuries to the medial malleolus and deltoid ligament in 107 stages 4 and 5 fractures

Supination fractures

S fractures made up 20.1 per cent (38/488) of all fractures. The stage division and the associated injuries are shown in Figure 9

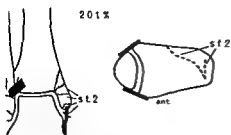
Stage 1 Fracture of the lateral malleolus at or distal to the level of the tibiotalar joint or rupture of the anterior talofibular and calcaneofibular ligament

Isolated ligamentous rupture is not included in this material. S1 fractures made up 80.1 per cent (79/98) of all S fractures. The injuries of the lateral malleolus are shown in Figure 10. At operation the ATFL

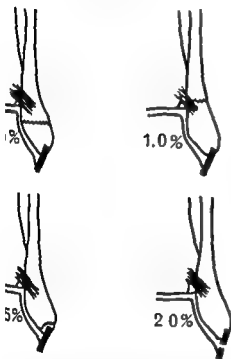
Figure 8 SE 5 fracture Typical spiral fracture of the distal part of the tibia a) Frontal view b) Lateral view

S fractures

201%



9 The stage division of supination (S) is according to Lauge Hansen



10 Stage 1 S fractures. Roentgenological, clinical and operative classification of the injuries to the medial malleolus and anterior talofibular and tibiocalcaneal ligaments (2 fractures with isolated ligamentous ruptures are not included)

found to be ruptured in one case and displaced from the tibia in another case

2 Fracture of the medial malleolus or fracture of the deltoid ligament, including 1

2 fractures made up 19.4 per cent (19/98) of all S fractures. In 63 per cent (12/19) of the fractures an oblique to vertical ($> 30^\circ$) fracture line was found, but transverse ($< 30^\circ$) fractures were also seen (Figure 11). The four cases of rupture of the deltoid ligament were not operatively explored. In a few cases a one-piece fracture of the posterior tibial margin and the medial malleolus was found (Figure 9).

Pronation and pronation-eversion fractures

P and PE fractures made up 20.9 per cent (102/488) of all malleolar fractures. The stage division and the associated injuries are shown in Figures 12 and 13.

Stage 1 Fracture of the medial malleolus or rupture of the deltoid ligament

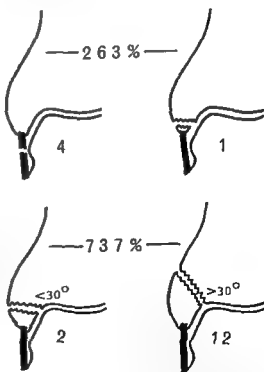


Figure 11 Stage 2 S fractures. Roentgenological, clinical and operative (7 pts) classification of the injuries to the medial malleolus and deltoid ligament in 17 S 2 fractures

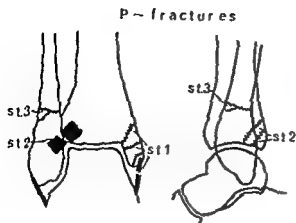


Figure 12 The stage division of pronation (P) fractures according to Lauge Hansen (1942)

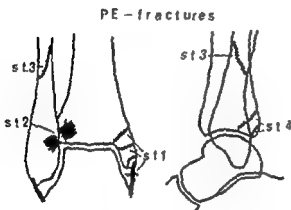


Figure 13 The stage division of pronation eversion (PE) fractures according to Lauge Hansen

According to Lauge Hansen (1942) the fracture-causing mechanism in stage 1 of P and PE fractures is identical. P/PE 1 made up 45.9 per cent (46/102) of all P and PE fractures. The occurrence of various stage 1 injuries in stages 2, 3 and 4 is shown in Figure 14. If the small avulsion fragments are looked on as rupture of the deltoid ligament, this type made up 58.5 per cent (33/46) of the medial injuries.

Stage 2 Rupture of the distal tibiofibular syndesmosis including stage 1.

Clinically and roentgenologically it is impossible to distinguish between stage 2 injuries of P and PE fractures, and so they

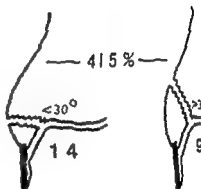
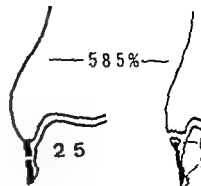


Figure 14 Stage 1 P and PE. Roentgenological, clinical and operative situation of the injuries to the medial malleolus. In 56 stages 2, 3 and 4.

will be classified as P/PE 2 fracture. Fractures made up 17.6 per cent (18) of all P and PE fractures. If a bone fragment from the posterior tibial tubercle is found, the diagnosis can only be made from the findings of the clinical examination: tenderness, swelling and often discoloration in front of and behind the lateral malleolus. The stage 2 injuries of 18 P/PE 2 are shown in Figure 15.

As regards P3 and PE3 and 4, the ligament was explored in 30 cases. Rupture of the ligament proper was found in 27 cases, and avulsion fragments from the anterior tubercle in three cases.

P stage 3 Low transverse supracondylar fracture of the femur including stage 2 (Figure 12).

P3 fractures made up only 7.8 per cent

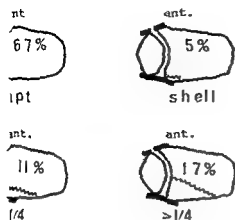


Figure 15 Stage 2 P and PE fractures
Roentgenological and clinical evaluation of 18 fractures

2) of all P and PE fractures
Roentgenological fracture of the posterior
margin was found in only one of these
fractures

Stage 3 High supramalleolar fracture of
fibular including stages 1 and 2 (Figure

The level of this fracture varies greatly as
shown in Figure 16. No fracture was less
than 25 cm above the tibiotalar joint. An
assessment of the course of the fibular
fracture was made from the lateral X-ray.
Seventy per cent (21/30) had a fracture line
running from the anterior fibular margin in a
distal direction (Figure 16a), 17 per
cent (3/30) had a fracture line running in the
proximal direction (Figure 16b) and 13 per
cent (4/30) had a transverse or comminute
fracture (Figure 16c). No cases had rupture of
proximal tibiofibular syndesmosis.

Figure 17 shows a PE 3 fracture with
dislocation of the talus and total rupture of the
syndesmosis but without any avulsion
fragment from the posterior tibial tubercle.

Stage 4 Fracture of the posterior tibial
margin including stages 1, 2 and 3.
The size of this fracture varies as shown in
Figure 18. The posterior tibiofibular ligament

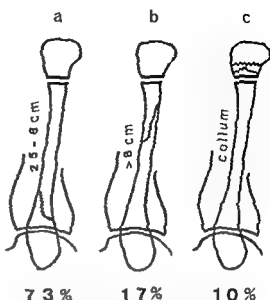


Figure 16 Stage 3 PE fractures
Roentgenological evaluation of the site of the distal end of the
fibular fracture in relation to the tibio-talar joint
and illustrations of typical fracture lines (a, b and
c) of 30 stage 3 and 4 fractures

is intact and the fragment is in this way
connected to the lateral malleolus. In 73 per
cent (8/11) of these cases the posterior
fragment included more than 25 per cent of
the joint surface.

Pronation-dorsiflexion fractures

These fractures made up 0.4 per cent
(2/488) of all malleolar fractures. Stage 1
includes fracture of the medial malleolus and
the anterior tibial margin. In this series one PD
1 fracture was found (Figure 19). In the one
stage 2 fracture an additional transverse fibular
fracture was found.

Isolated fracture of the posterior tibial margin

These fractures made up 0.4 per cent
(2/488) of all malleolar fractures. These
fractures were found in a series of 18
patients, age range from 23-44 years. Three stumbled and
one fell down 2 meters.

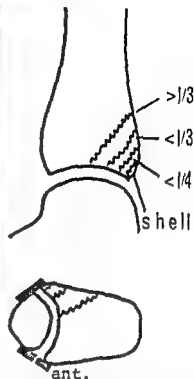


Figure 18 Stage 4 PE fractures Roentz evaluation of the fracture of the poster margin in 11 stage 4 fractures

DISCUSSION

In the present material 98.8 per cent malleolar fractures could be classified according to Lauge Hansen's which consequently must be considered suitable for the characterization of fractures. This is in agreement with investigations of Kristensen (1953), Bus Charnley (1965) and Maatz & Nent (1973) whose results showed that between 85 and 99 per cent of these fractures could be classified according to Lauge Hansen.

The roentgenological and intraoperative findings also corresponded well to observations of Lauge Hansen (1942) in the case of SE fractures and the findings of Cedell (1967).

Figure 17 PE 3 fracture Total lateral dislocation of the talus with complete rupture of the desmosis but without fracture of the tibial tubercle a) Frontal view b) Lateral



Figure 19 Stage 1 pronation dorsiflexion (PD) fractures according to Lauge Hansen. a) Frontal view b) Lateral view

However, for P and PE fractures the serious injuries of the syndesmosis do seem to be fully explained by Lauge Hansen (1942). Concerning the stages 2, 3 and 4 (cf. Figure 17) it seems that the anterior tibiofibular ligament is found to be injured in cases without fracture of the posterior tibial margin (Weber 1966). Thus a fracture of the posterior tibial margin is even in cases of PE fractures precedes a bimalleolar fracture as a stage 2 injury and not stage 4 injury as supposed by Lauge Hansen.

As shown in Figures 7, 11 and 14 injuries of the deltoid ligament and the medial malleolus are not pathognomonic for the various types of fractures as found by Lauge Hansen (1942). In SE fractures the transverse fracture is most frequently seen, in S fractures the oblique ($> 30^\circ$) fracture and in

P/PE fractures almost equal frequency is seen.

Lauge Hansen (1942) and Kristensen (1953) did not find any isolated fractures of the posterior tibial margin. This fracture is, however, described by Magnusson (1944), Frank (1941) and Bonnan (1950). In the four cases found in this material the deltoid ligament was not explored and the clinical estimate cannot be considered to be completely reliable. However, in January 1979, a case of posterior marginal fracture was examined by the author and it was not possible to establish tenderness, swelling or discoloration over the deltoid or the anterior talofibular and calcaneofibular ligaments.

As shown in this paper the Lauge Hansen classification gives a very precise and detailed description of malleolar fractures. A classification of this type is an excellent and necessary

means of conducting a comparable evaluation of results of various types of treatment of malleolar fractures.

In clinical work this classification is also very useful because it gives important information about ligamentous injuries which may accompany the fractures seen roentgenologically.

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ONIC LATERAL INSTABILITY OF THE ANKLE

hod of Reconstruction Using the Achilles Tendon

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Reconstruction of the lateral ankle ligaments *ad modum* Støren using the medial one third of the Achilles tendon as a nourished transplant is a relatively unknown procedure. Thirty patients operated on using this technique have been evaluated. The mean observation time was 4 years (range $\frac{1}{2}$ -16 years). All patients but one had a stable ankle joint and were satisfied. One was reoperated after sustaining a new injury 8 months after the original operation. The method described is a good alternative to other methods of ligamentous reconstruction. The procedure also stabilizes the subtalar joint and corrects recurrent subluxation of the peroneal tendons.

Key words Achilles tendon, chronic ankle instability, lateral ankle ligaments, ligamentous reconstruction

Accepted 12 v 79

ent instability, pain and muscular
ess following rupture of the lateral
nts of the ankle is a frequent problem
nan 1965, Freeman et al 1965)
rvative treatment should be tried before
al procedures. Direct suture of the torn
nts (Broström 1966, Solheim & Aasen
and ligamentous reconstruction using
troneus brevis (Chrisman & Snook 1969,
son 1978, Watson-Jones 1955) or the
cus longus tendon (Zenni et al 1977)
all known procedures.

ren (1959), using the medial one third of
chilles tendon as a nourished transplant
onstruction of the lateral ligaments,
ed the importance of the fact that this
d does not interfere with the function
e peroneal tendons thus retaining the
e muscular balance of the foot. Beside
e preliminary report (Denstad & Solheim
' there has been no other report of this
d. This paper presents the result and
modifications of the original operative
dure.

PATIENTS AND METHODS

Between the years 1962-1978, 30 patients with chronic lateral instability of the ankle joint were operated on using the original or a modified Støren procedure. There were 20 male and 10 female patients with an average age of 35 years (range 19-55 years). The right ankle was involved in 19 and the left in 11 patients. All patients gave a history of primary severe sprain, which in the majority of cases had been insufficiently treated, and later chronic unstable ankles for periods ranging from $\frac{1}{2}$ -20 years (mean 8 years). On physical examination all patients had instability of the ankle by forced inversion and/or the anterior drawer sign. Anteroposterior and lateral stress X-rays showed marked tilting and anterior subluxation of the talus in most of the patients.

The operative findings showed seven isolated ruptures of the anterior talofibular ligament and two of the calcaneofibular ligament whereas 17 patients had ruptures of both ligaments. In four patients the ligaments were not dissected free. Additional subtalar instability with rupture of the talocalcaneal ligament was found in seven of the patients and two had subluxation of the peroneal tendons.

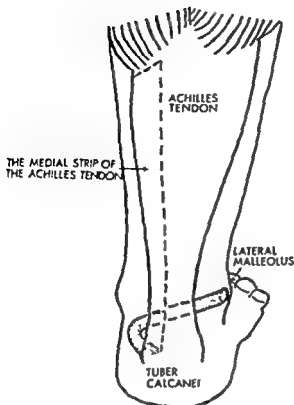
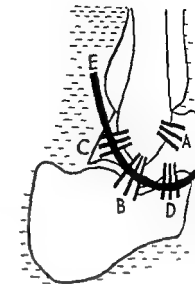


Figure 1 Dorsal view of the medial one third of the free dissected, reflected and transposed Achilles tendon

Operative procedure

First session Through a posteromedial longitudinal incision the medial one third of the Achilles tendon is dissected free, transected proximally at the musculotendinous junction and reflected distally without separating it from the distal insertion on the calcaneus (Figure 1). Støren exposed the region of the lateral malleolus through an anteriorly curved incision in front of the malleolus, but a curved incision behind the malleolus is preferable (Figure 2). The short extensor digitorum muscle is retracted anteriorly to expose the neck of talus, sinus tarsi and the lateral aspect of calcaneus. The free dissected tendon transplant is then pulled through to the lateral side in front of the remaining two thirds of the Achilles tendon and guided subcutaneously deep to the sural nerve but superficially past the peroneal tendons to the lateral malleolus. The tendon is now threaded through a drill hole in the lateral malleolus, a second drill hole in the neck of the talus and a third drill hole through the lateral aspect of the calcaneus. To prevent limitation of dorsiflexion of the ankle the tendon should be fixed to the fibula with the ankle in dorsiflexion



talofibular ligament, B = calcaneofibular ligament, C = posterior talofibular ligament, D = caneal ligament)

before it is tightened and sutured to the peroneum at the other holes. When the tendon is long enough, it is passed back to the lateral malleolus and sutured to the talofibular ligament (Figure 3). This modification was performed in 10 patients.

Second session If instability of the ankle after this operation Støren recommends a second session to take place a minimum of 4 weeks after the first session (Figure 4).

Postoperative treatment

Mean hospital stay was 14 days. Immobilization in plaster postoperatively was continued for 6 weeks, the last 4 weeks with a walking cast, followed by intensive physical therapy.

Follow-up examination

The follow-up period after the operation was 4–16 years, mean 4 years. All patients completed a questionnaire and 16 patients were personally examined.

RESULTS

Twenty patients rated their function as excellent without complaints and

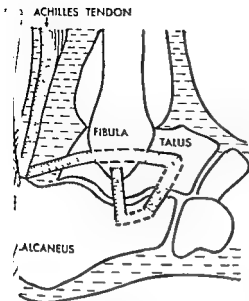


Figure 3 The completed modified procedure of anolous reconstruction employing the medial end of the Achilles tendon

with slight complaints such as sporadic distortions (2 patients), occasional rate swelling (3 patients), slight pain on exertion (4 patients), a little limited flexion or inversion (6 patients) and anal symptoms from the Achilles tendon (patients). Of the 16 patients examined initially all had a stable ankle. Eleven out of 13 competitive athletes were able to resume their previous sporting activity. Immediate postoperative complications included one case of superficial infection and two of wound necrosis all of which healed. One patient was reoperated after sustaining a new injury 6 months after the operation. The second session of the operation was used and, in addition, tarsal tunnel decompression, using the peroneus brevis on.

DISCUSSION

Allen (1959) reported seven operations, three of them being two session operations, all giving satisfactory results. In our experience

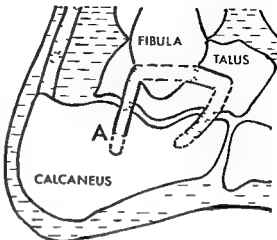


Figure 4 The second session of Støren's original procedure the posterior part of the transposed tendon has been freed from its insertion medially on the tuberosity of the calcaneus and fixed at the insertion of the calcaneofibular ligament on the calcaneus (A)

the first session of the operation is sufficient. The transposition of the Achilles tendon in front of the malleolus represents a reconstruction of the anterior talofibular ligament. Our modified procedure, guiding the tendon back to the fibula, represents a reconstruction of the calcaneofibular ligament, making the second session of the operation unnecessary.

Subtalar instability may occur after sprain causing rupture of the talocalcaneal ligament (Rubin & Witten 1960, Meyer & Lagier 1977) as well as the calcaneofibular ligament (Chrisman & Snook 1969, Brantigan et al. 1977) and should be diagnosed pre- or intraoperatively, since the most commonly used Watson-Jones procedure will not correct this instability (Gillespie & Boucher 1971, Brantigan et al. 1977). Chrisman & Snook (1969) recommend a modification of the Elmslie procedure using half of the peroneus brevis tendon for treatment of talar and subtalar instability. Brantigan et al. (1977) reported involvement of the subtalar joint in about 10 per cent of patients with lateral instability of the ankle compared with the 23 per cent in our material. This might be due

to the long preoperative period of ankle instability and to the exposure of the subtalar joint by this operation. The stabilizing effect on the subtalar joint with this operation is satisfactory.

Recurrent anterior displacement of the peroneal tendons due to tearing of the superior peroneal retinaculum may complicate sprains of the lateral ligaments (Anderson & LeCocq 1954). Two of our patients developed subluxation of the peroneal tendons after a long period of lateral ankle joint instability. The method described corrects this condition as well as the instability of the ankle.

Our results are comparable with those of other methods of ligamentous reconstruction. The method seems especially valuable in the treatment of combined talar and subtalar instability or when additional subluxation of the peroneal tendons occurs. The operative procedure is, however, somewhat extensive and the method should perhaps be reserved for cases of more severe instability.

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VASCULARIZATION OF FREE PERIOSTEAL AND 100 MICRON THICK OSTEOPERIOSTEAL GRAFTS IN A MUSCLE TISSUE ENVIRONMENT

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The vascularization of free periosteal and 100 micron thick osteoperiosteal grafts was studied in growing rabbits. Sixteen rabbits with 32 periosteal and 32 osteoperiosteal grafts were operated upon and microangiographed 1-21 days postoperatively. The vascularization of free periosteal grafts started 1 day postoperatively and that of osteoperiosteal grafts 3 days postoperatively. The first capillaries seemed to enter through the cambium layer in periosteal grafts and through the cortex in osteoperiosteal grafts.

Key words: microangiography, osteoperiosteal graft, periosteal graft, vascularization

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A direct relationship between vascularization and osteogenesis was proposed by von Reckhow as early as 1763, but only during the last 20 years has technical progress focused attention on the anatomy of the circulation of bone. The study of the microscopical level (Rhemelander 1962, Brookes 1964, Trueta 1963, Brookes 1964, Trueta 1963, Rhemelander 1972). Today our knowledge of the circulation of cortical bone is mainly based on many animal experiments performed by Trueta (1968), Brookes (1971) and Rhemelander (1972). According to these studies the circulation of a long bone has three main sources: the nutrient artery, the metaphyseal and diaphyseal arteries and the periosteal arteries. In a functional sense two different theories concerning the circulation in cortical bone, especially regarding its outer third, are in existence. 1) According to Brookes (1971) and Rhemelander (1972) the medullary circulation is afferent, the direction of flow in the diaphyseal cortex is centrifugal. This means that the periosteal arteries serve only as com-

municating vessels between the bone and the soft tissue, usually muscle, as the final ring of the afferent system. According to the dual circulation concept (Trueta 1963, 1968) the medullary, metaphyseal and the epiphyseal vessels contribute to the circulation of the inner two thirds of the cortex, the outer third being supplied by the periosteal vessels. Agreement between these theories is however reached when considering a situation where the medullary circulation is disturbed. Then the extrasosseous vessels proliferate, produce new periosteal bone and also nourish the outer lamellae of the cortex (Trueta 1963, Danckwardt-Lilliestrom 1969, 1970 and Rhemelander 1972). In our previous studies (Poussa & Ritsila 1979, Poussa et al 1980) a comparison was made between the osteogenic properties of a free periosteal graft and 100 micron and 200 micron thick osteoperiosteal grafts. The 200 micron thick osteoperiosteum was inferior to both other grafts osteogenically. On the other hand only a minor

difference could be seen between the behaviour of the free periosteum and that of the 100 micron thick osteoperiosteum. During the first 3 postoperative days the cambium layer cells of the free periosteum seemed to proliferate more vigorously than the corresponding cells in the 100 micron thick osteoperiosteum. Therefore a study was made of the development of the vascularization in these two grafts.

Special attention was paid to the direction from which the vessels invading the periosteal and osteoperiosteal grafts came, and to the possible differences in the intensity of the vascularization between the two grafts. The question regarding the direction of the vascularization is of special interest, because of the different opinions about the direction of the flow in the periosteal vessels *in situ*.

MATERIAL AND METHODS

Sixteen 6-week-old rabbits were operated upon. In each one free periosteal and 100 micron thick osteoperiosteal grafts were detached from the medial facet of the tibia and then fixed to two adjacent lumbar vertebrae between the spinous and mamillary processes, so that altogether 32 periosteal and 32 osteoperiosteal grafts were studied. Details of the operation technique have been described in a previous paper (Poussa & Ritsila 1979). On days 1, 2, 3, 4, 5, 6, 7, 9, 14 and 21 the vascularization of the grafts was studied by a technique presented by Jarvinen (1976) being a modification of the technique used by Wendelin & Lindgren (1970) and Chaplin (1973).

The animals were anaesthetized with intramuscular Hypnorm* (Philips, Duphar 0.5 ml/kg) a laparotomy was made through the midline incision and the abdominal aorta was cannulated through the bifurcation the tip of the catheter pointing towards the heart. A catgut thread was tied around the distal abdominal aorta and the cannula so that there was no circulation to the lower extremities. Next 5000 units of Heparin was injected into the aorta, followed by physiological saline solutions temperature 32–37°C, perfused at a constant pressure of about 100 mmHg (the container was positioned about 1.3 m above the rabbit). The pressure in the abdominal aorta was also controlled by hydrostatic measurement. At the beginning of the infusion the pressure in fact was about 100 mmHg when measured just proximal to the needle that was

in the abdominal aorta. Later on, especially the animal died there was a mild decrease in pressure to about 90 mmHg. After 5 min perfusion was continued using a warm, 3% per cent radiopaque suspension (Crom-Damancy & Co. Ltd. England) for about 20 min. Thereafter the perfusion mixture was changed to 10 per cent Cromopaque* diluted in 10 per cent buffered formalin. The rabbit usually died during the first 20 minutes of the infusion. Then the animal was totally immersed in 10 per cent formalin solution for 24 hours. The vertebra with surrounding muscles were then detached and kept about a week in a formalin solution.

The extra muscles around the vertebra were removed and the samples were fixed in formic acid, dehydrated in graded alcohols, cleared in xylene and toluene and embedded in paraffin and beeswax. Serial 5 µm thick sections were cut horizontally through the blocks. Because the width of the grafts was approximately 4–5 mm only two to three 5 µm thick sections were obtained from each vertebra during the first postoperative day on possibly because the newly formed vessels 'sprouting' over the edges of the grafts. A number of sections was obtained from each vertebra. The distribution of the sections at various intervals is presented in the following table.

Postop day	No of sections studied
1	4
2	6
3	6
4	8
5	3
6	4
7	15
9	5
14	9
21	13
	73

These sections were placed in contact with photographic emulsion (Kodak High Resolution Plate, USA). A Machlett AEG-50 roentgen tube with a 1.5 mm focal spot and equipped with a 0.5 mm beryllium window was employed. This was done at 30 kV. The film focus distance was 0.5 m. Sections measuring 6 µm were made from each sample to get the histological counterpart of the microangiogram.



1A Microangiogram ($\times 5$) 1 day after. The grafts in the microangiogram as shadows. In the periosteal graft (P) some contrast media are seen also incipient projections of capillaries from the mamillary process OP osteoperiosteum)



Figure 1B Histological picture ($\times 250$ Van Gieson) from the microangiogram of the free periosteum 1 day postoperatively. Proliferation of the cambium layer (CL) is clearly seen in association with contrast medium filled capillaries (Ca) (FB—fibrotic layer of the periosteum M—muscle)

TS

The filling of the vessels in the slices and also in the vicinity of the grafts and the loose layer covering the grafts was a loose mass a narrow gap separated from the underlying grafts. This was obviously an artefact arising during the section of the sample.

In the microangiogram of the periosteum a number of contrast medium were seen (1A). In the histological study the cambium layer of the grafted periosteum was seen to proliferate with some contrast medium filled vessels (Figure 1B). These contrast medium filled vessels were seen in all the four sections studied.

In the osteoperiosteum neither the cortex nor the periosteum were seen to have contrast medium filled vessels. In the histological counterpart no proliferation of the cambium layer was seen.

In the microangiogram of the periosteum sprouting of the capillaries was seen to occur from the underlying tissue near the mamillary process (Figure 2A). In the histological study the thickened and proliferating cambium layer was seen with wide contrast filled vessels (Figure 2B). Incipient vascularization of the periosteum was seen in five of the six sections.

In the 100 micron thick osteoperiosteum no corresponding capillary ingrowth could be seen. Also no ingrowth of capillaries was observed on the other side of the grafts i.e. through the fibrotic layer of the periosteum (Figure 2A).

Day 3 The whole periosteal graft was vascularized and capillaries were sprouting from the underlying muscle and to a minor degree from the muscle above (Figure 3).

In the 100 micron thick osteoperiosteum incipient invasion of the capillaries from the underlying tissue was seen the cortical part of the grafts being invaded first.

Six 1000 micron thick sections were studied periosteal vascularization was seen in four and osteoperiosteal in two.

Days 4-5 Circulation was present in both the periosteal and osteoperiosteal grafts. The intensity of the vascularization seemed to be directly related to the intensity of the new bone formation or *vice versa*. In the histological study contrast filled vessels were seen in the cambium layer in the newly formed bone and also in the fibrotic layer of the periosteum.

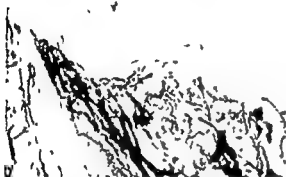


Figure 2A. Microangiogram ($\times 5$) 2 days postoperatively. There is capillary sprouting in the cambium layer of the free periosteal graft from the underlying muscle. This is better seen in the higher magnification ($\times 40$). The 100 micron thick osteoperiosteum looks inactive.

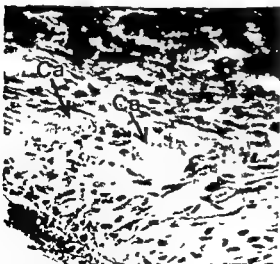


Figure 2B. Histological picture from the microangiogram of the free periosteum 2 days postoperatively ($\times 250$). Wide contrast medium filled capillaries (Ca) are seen in the proliferating cambium layer.



Figure 3. Microangiogram ($\times 6$ magnifications $\times 40$) from the lumbar 1 days postoperatively. On the periosteum there is circulation which seems to be more the part facing the underlying muscle.

point (arrow.)



Figure 4B Histological picture from the

together eleven sections were obtained in all of them vigorous vascularization was seen

6 7 There was vigorous circulation in periosteal and osteoperiosteal grafts (see 4A) In the histological study new bone had been formed by both the periosteal and the osteoperiosteal grafts The new bone

the gap seen in the microangiogram

formed by the periosteum was seen to have a well developed circulation with its surroundings On the other hand in most of the ossicles formed by the osteoperiosteum there was some kind of frontier through which the vascular communications between the bone

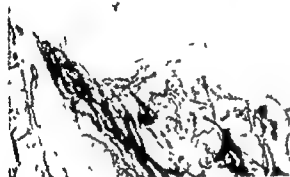


Figure 2A Microangiogram ($\times 5$) 2 days postoperatively. There is capillary sprouting in the cambium layer of the free periosteal graft from the underlying muscle. This is better seen in the higher magnification ($\times 40$). The 100 micron thick os teoperiosteum looks inactive.



Figure 2B Histological picture from the microangiogram of the free periosteum 2 days postoperatively ($\times 250$). Wide contrast medium filled capillaries (Ca) are seen in the proliferating cambium layer.



Figure 3 Microangiogram (\times magnifications $\times 40$) from the lower part of the graft 2 days postoperatively. On the part facing the underlying muscle there is circulation which seems to be in the part facing the underlying muscle. In the cortical part of the graft, incipient vascularization possibly from the periosteum especially from the lat point (arrow).

In no other studies dealing with the vascularization of free periosteal grafts have the prerequisites for osteogenesis also in skin grafting has been emphasized by the author (King (1976) and Finley et al (1978)). The senior author produced new bone in skin grafts by periosteal grafts based on the fact that the latter authors transplanted free periosteal grafts by preserving the circulation and microvascular anastomoses between the grafts and the host vessels. Finley et al used skin grafts as controls. In no case was new bone formation observed in the control group.

On the other hand there are numerous studies dealing with the physiology of skin grafts which in some aspects resemble bone grafts. In skin grafting it has been postulated prior to establishment of the grafts are nourished by the diffusion of gases and nutrients across the grafted bed interface (Smahel). Also in skin grafts the ingrowth of new blood vessels into the graft from the bed is considered negligible; the main blood supply of the grafts coming from the anastomoses with the existing vessels (Smahel & Smith (1970)).

On the other hand the revascularization of bone grafts is said to occur mainly by capillary sprouting (Stringa 1957, Zeiss et al and Rhinelander 1972). Also contrary to the above presented (Deleu & Trueta 1963) These authors implanted small bone grafts into the anterior chamber of rats and

pigs and concluded that only anastomosis between the pre-existing host vessels could explain the rapid vascularization of the grafts. The sizes of the vessels were "one to two millimeters".

In the present study contrast medium was injected into the cambium layer capillaries 1 day postoperatively. From the microangiogram and histological slides it is difficult to see whether an anastomosis between the pre-existing vessels of the bed and the graft has taken place or if this revascularization has occurred through capillary sprouting.

Stringa (1957) found that capillary

sprouting penetrated into autogenous grafts with a speed of 3 mm per 7 days from the kidney bed in rabbits and guinea pigs. Also it has been reported by Danckwardt Lilliestrom (1969) that after reaming the medullary cavity of a rabbit femur new capillaries can be seen after 24 hours. Clark & Clark (1939) found that capillaries grew with a speed of 0.22 mm per day in the transparent chamber of the rabbit's ear.

From 2 days on postoperatively it was seen that the vascularization of free periosteal grafts occurred by capillary sprouting from the bed through the cambium layer. Revascularization was achieved by periosteal grafts about 2 days earlier than the 100 micron thick osteoperiosteal grafts.

In some earlier reports it has been postulated that during the first few days of bone transplantation the nutrition of the grafts is achieved by diffusion (Ham). On the other hand in some of the studies (Graf (1960), Trueta (1963), Deleu & Trueta (1965) and Tervo (1976)) concerning the speed of vascularization it was found that the vascular penetration preceded the formation of secondary osteons. A similar conclusion can be drawn from the present study. New bone formation was seen 4-5 days postoperatively in both periosteal and osteoperiosteal grafts but contrast medium was visible in periosteal grafts as early as 1 day postoperatively and in osteoperiosteal grafts 3 days postoperatively.

In this study the capillary sprouting during the first few days was seen to come from the bed below through the cambium layer of the periosteal grafts but between the bed above and the fibrotic layer of the periosteal as well as the osteoperiosteal grafts as late as 3 or 4 days postoperatively. As a result of the operation trauma the muscle layer covering the grafts was exposed to much greater damage than the muscle layer beneath the graft. The direction of sprouting may have been different if the grafts had been fixed in another way, i.e. with the cambium layer of the free periosteum and the cortex of the osteoperiosteum in contact with the muscle above.

representation is obtained. At the time when the records were searched for information about the alcoholics and their controls there was a 28-year roentgen history of the residents of the city available for study. The files were searched for records of roentgen examinations in the same manner for all 321 men involved in the study. Altogether 3242 roentgen referrals were scrutinized. The following variables were recorded:

- a) The total number of fractures over the years.
- b) The number of fragility fractures—vertebral crush fracture, fracture of the upper end of the femur, fracture of the upper end of the humerus, fracture of the distal end of the forearm, ankle fracture and fracture of the lateral tibia condyle (Nilsson & Westlin 1977).
- c) The total number of skull roentgen examinations and the number of skull fractures.
- d) The total number of fractures occurring in conjunction with industrial accidents and traffic accidents.
- e) Gastro-duodenal roentgen examinations, total number of "first" examinations excluding all follow-up examinations related to ulcer. Also, the number of the gastro-duodenal peptic ulcers diagnosed over the years.
- f) The number of *iv* urographies, again only "first" urographies and not serial investigations, and the number of kidney stones diagnosed over the years.

RESULTS

The average number of roentgen examinations was 14 for alcoholics and 8 for the controls. The number of fractures (Table 1) was almost quadrupled in the alcoholics compared with the controls and so was the number of fragility fractures. The difference as in both instances significant ($P < 0.001$).

The number of skull roentgen examinations, again, was significantly increased ($P < 0.001$)—by a factor of more than 4—in the alcoholics but the large number of roentgen examinations did not reveal an increased number of skull fractures. The number of industrial accident related fractures was not significantly increased in the alcoholics. The number of traffic accidents, however, was increased ($P < 0.001$) but in relation to the total number of fractures, the traffic accident fractures were not significantly more common in the

■ Chi-square test.

Table 1 Radiographic examinations and in 100 alcoholics and age-matched controls

	Alcoholics	Controls
Total fractures	93	41
Fragility fractures	41	69
Skull roentgen	69	3
Skull fractures	3	11
Industrial accident fractures	11	13
Traffic accident fractures	13	147
Gastro-duodenal roentgen	147	32
Gastro-duodenal ulcer	32	50
<i>Iv</i> urography	50	10
Kidney stones	10	

alcoholics. The number of gastro roentgen examinations and gastro ulcers was increased by about half in alcoholics as compared with the controls. The proportion of positive and negative roentgen examinations was about the same in both groups. Finally, *iv* urography with a positive finding of stones did not differ significantly between alcoholics and

DISCUSSION

Misusers of alcohol are an important group of medical consumers. The elderly perhaps the most important—group of medical consumers. Consumption of medical care also related to roentgen diagnosis to an extent far above the average. The diagnostic procedures always fruitful, skull roentgen examinations as shown above yield very little information but are nevertheless frequently used for differential diagnosis of intoxication and traumatic neurologic conditions. For fracture examinations, however, the proportion of negatives was less in the alcoholics than in the controls. For some diagnostic procedures such as gastro-duodenal roentgen examination, the proportion of alcoholics having a positive finding was moderate and easily explained by an increased prevalence of gastro ulcers. With regard to other

procedures such as i.v. urography seems to be without importance. The most striking finding in this study is, however, the increased rate of fracture in spite of the known relationship between alcoholism and fragility fractures in the elderly, as demonstrated in the case of fracture of the neck of the femur and fracture of the upper end of the humerus (Nilsson, Horak & Nilsson 1975). The number of fractures amounted to the same as the total in the alcoholics as in the controls. This is probably explained by the fact that the alcoholics during most of the study period were covered by the study had not yet reached the age when fragility fractures are a serious problem.

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EFFECT OF AXIAL TENSION ON THE LOAD HOLDING CAPACITY OF TRACTION PINS*

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Skeletal traction is often used in the conservative treatment of fractures. Although a small diameter traction pin causes less trauma, its use is limited by the strength of the pin and the holding power of the bone. Both theoretical analysis and *in vitro* experiments were conducted to investigate the bending resistance of traction pins subjected to an applied traction force. The results of this study indicate that thin K-wires could be used successfully as traction pins. Excessive bending of these wires could be prevented by applying tension. The possibility of a pin cutting through bone is minimal if the cortical bone structure of the patient is normal. However, further *in vivo* study is necessary to ascertain whether necrosis might occur due to excessive contact stress between the pin and the bone.

Key words: K-wires, skeletal traction, tension, traction pins

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ure of a long bone is a common problem
thopaedic surgery. At times such a
ure must be treated non-surgically, at
temporarily, whether due to associated
es, or due to the type of fracture itself.
such conservative treatment is the
od of choice, as open reduction is always
npanied by the risk of infection (Albright
1978). However, contractures or spasms
the muscles surrounding fractures of long
s sometimes tend to cause overriding or
lation of the fragments, which may be
ult to reduce by manual manipulation.
: This is particularly true in oblique and

comminuted fractures of the long bones such
as the femur (DePalma 1970). In such cases a
continuous traction force is generally applied
on the distal fragment to overcome muscle
pull, correct the angulation and restore the
length. Even when anatomical reduction has
been achieved, traction is often employed to
maintain the length and alignment. Generally
more force is necessary for the reduction
phase than for the maintenance, and therefore
some authors make a distinction between
reduction traction and maintenance traction
(McElvenny 1963).

In the case of a limb, there are two
methods of applying traction: (a) the force
may be applied through the skin which is
called skin traction, or (b) the force is applied
directly to the bone by means of a metal pin
or wire which is driven through the bone, as
shown in Figure 1, and this is called skeletal
traction (Stewart 1975). Although skin

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Figure 1 Skeletal traction being applied to the distal femur for reducing a femoral fracture

traction is less traumatic, it can be applied only for limited time periods and for small loads. It is generally used for maintenance traction only (McElvenny 1963). According to Stewart (1975) the maximum traction weight which can be applied with skin traction is 15 lb (6.7 kg), but McElvenny (1963) has suggested that the weight should be less than 8 lb for the lower extremity and less than 4 lb for the upper extremity. Therefore, when a substantial amount of weight is needed, or when prolonged traction is indicated, pin traction is generally used (Figure 1). Traction on a pin which transverses the bone often does not cause pain, assuming that soft tissue irritation is prevented at the points of exit on either side.

Two types of pins are commonly used in orthopaedic surgery: (1) Kirschner wires (K-wires) which have a small diameter (0.025 to 0.062 inches or 0.6 to 1.6 millimeter) and (2) Steinmann pins which are larger ($\frac{1}{16}$ to $\frac{1}{4}$ inches or 2 to 4.8 millimeters). Although use of a small diameter pin is preferred as it causes less trauma, K-wires tend to bend if the traction load is large. Recently, Morgan et al (1976) have suggested that the bending resistance of small pins can be improved by using pins made of stiffer materials such as tungsten fibre reinforced composite. The bending resistance of metal pins can also be improved by applying an axial tension with the help of a Kirschner wire strainer (as shown in Figure 2) (Albright et al 1978). However, no quantitative data is available on the effect of axial tension in reducing deflection of metal pins due to bending.

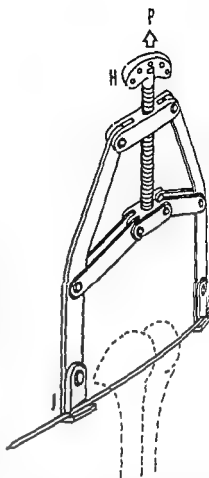


Figure 2 Kirschner bow or wire strainer is held between serrated jaws J. Turn handle (H) increases the distance between J, producing axial tension in the position of the bone is shown by a dotted line. P indicates the traction force.

The objective of this investigation is to study the effect of applied tension on the resistance of pins to bending due to the load. As another objection to using small diameter pins is the possibility of cutting through bone, experiments were carried out to determine if thin K-wires under normal traction loads produce so much contact stress to cut through bone.

THEORETICAL ANALYSIS

Nomenclature

D—Diameter of the pin
E—Modulus of elasticity

moment of inertia of the pin
 of the pin projected beyond the bone
 ion force
 on in the pin
 coordinates along the length of the pin, and
 the pin, respectively

$\frac{T}{EI}$
 maximum deflection of the pin at $x=L$
 bending resistance of a traction pin
 to a traction force P and an axial tension
 be analyzed by treating the pin as a
 beam of length L as shown in Figure 3
 as cantilever beam model and assuming
 deflection to be small and the stress strain
 to be linear and elastic, one can show
 differential equation governing the deflec-
 of the beam is given by (Timoshenko &
 71)

$$EI \frac{d^2 y}{dx^2} = T(\delta - y) - \frac{P}{2}(L - x) \quad (1)$$

E is the modulus of elasticity, I is the
 of inertia of the pin and δ is the
 deflection at $x=L$. The general solution
 n (1) is

$$C_1 e^{\beta x} + C_2 e^{-\beta x} + \left(\frac{PL}{2T} - \frac{Px}{2T} - \delta \right) \quad (2)$$

$\beta^2 = \frac{T}{EI}$ and the first two terms are the
 us solution of the differential equation
 the term within the parenthesis is the
 solution (Boyce & DiPrima 1969). The
 constants C_1 and C_2 can be evaluated by
 the boundary conditions $y=0$ and $\frac{dy}{dx}=0$

at end $x=0$. Substitution of C_1 and C_2
 the solution

$$y = \left(-\frac{PL}{4T} + \frac{P}{4T\beta} + \frac{\delta}{2} \right) e^{\beta x} + \left(-\frac{PL}{4T} - \frac{P}{4T\beta} + \frac{\delta}{2} \right) e^{-\beta x} + \frac{PL}{2T} - \frac{Px}{2T} - \delta \quad (3)$$

to be evaluated by using the relation at
 $y(L)=\delta$. Using this relation and after some
 we get

$$\frac{\delta}{P} = \frac{1}{2T} \left[L - \frac{1}{\beta} (e^{2\beta L} - 1)(e^{2\beta L} + 1)^{-1} \right] \quad (4)$$

is utilized to determine the effect of
 axial tension T and pin diameter D on
 maximum deflection δ per unit traction force

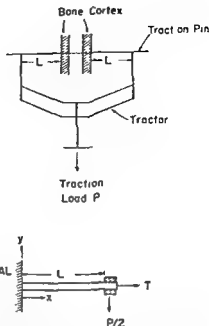


Figure 3 Cantilever beam model of the traction pin showing the axial tension force T and traction load P , and the co-ordinate system used

EXPERIMENTAL METHOD

Experiments were carried out on the bending behavior of a small diameter pin ($D=0.062$ inch or 1.6 millimeter) using embalmed human and fresh beef bones. The pin was inserted into the mid shaft of an embalmed human femur and subjected to a maximum axial tensile force which could be applied manually by a Kirschner wire strainer. Then traction loads were applied and maintained for about 12 hours. The traction load was increased in steps of 10 lb (44.5 N) up to a maximum of 50 lb (222.4 N). For each traction load the maximum deflection of the pin was measured from its undeflected position with the help of a millimeter scale. Similar tests were also conducted using an embalmed human tibia.

Small diameter pins were also inserted through the epiphyses of embalmed human tibias and femurs and similar tests, as mentioned before were repeated. The test set up is shown in Figure 4. At the end of each test the bones were examined for the evidence of any damage at the point of insertion of the pin.

RESULTS AND DISCUSSION

The numerical results from the theoretical analysis are shown in Figures 5 and 6. Figure 5 shows the maximum deflection (δ) of the

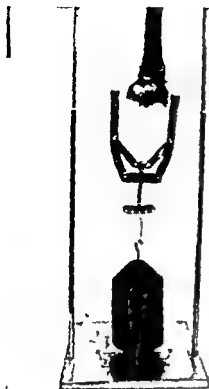


Figure 4 Experimental set up showing a thin K-wire (0.062 inches in diameter) through the epiphysis of a human tibia subjected to an axial tension applied by a Kirschner wire strainer and a 50 lb traction load

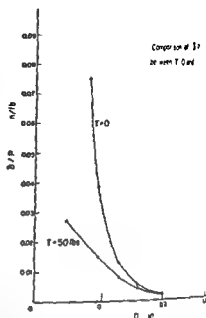


Figure 6 Relationship between the maximum deflection (δ) and the pin diameter D for tensile load levels, $T=0$ and $T=50$ lb.

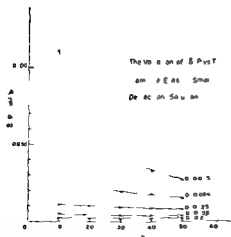


Figure 5 Maximum deflection (δ) of different diameter traction pins as a function of the axial tension (T) in the pin

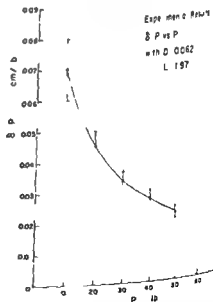


Figure 7 Variation of maximum deflection (δ) as a function of the unit traction load P as a function of the axial tension (P) applied by the Kirschner wire strainer

unit traction force (P) as a function of tension (T) in the pin, for various π pins. It is clear that for large π pins (diameter 0.125 inch or 3.2 mm and above) deflection remains unaffected by the tension T in the pin. For small diameter pins the deflection is significantly reduced as the tension in the wire is increased.

The maximum deflection δ per unit traction force P has also been plotted as a function of the pin diameter D for two axial traction forces $T=0$ and $T=50$ lb or 222.4 N.

6) Figure 6 shows that for small π pins (say $D < 0.125$ in or 3.2 mm) the maximum deflection without a tensile force T is significantly larger than when an axial tensile force $T=50$ lb (222.4 N) is applied. However this tensile force does not affect the bending resistance of pins of diameter D larger than 0.2 in (5.1 mm).

Figure 7 shows the maximum deflection of π pins, measured experimentally, per unit traction force as a function of increasing axial traction force P . It clearly shows that due to increasing axial tension, the deflection per unit traction force decreases as the traction load is increased and for a moderate traction load, the deflection is small.

It should be pointed out that as the maximum deflection δ is increased, the bending moment on the pin due to the traction force P remains almost unaffected. The corrective bending moment due to axial tension increases in direct proportion to δ . As the free end of the pin is held by a wire strainer, additional bending also occurs to increase the length of the pin and therefore increases the axial tension.

To examine the possibility of small diameter pins under normal traction load passing through the bone, laboratory tests were conducted using embalmed human Kirschner wires (0.062 in or 1.6 mm diameter) were inserted through the distal cortex and the wire was subjected to traction by using a traction bow. There was no sign of the wire cutting through the bone even when a maximum traction load of

50 lb (222.4 N) was applied for more than 12 hours.

When a similar test was conducted on K-wires inserted through the distal epiphyses, the wire still sustained the traction load without cutting through the bone so long as the thin shell of cortical epiphyseal bone was intact. However, for those specimens in which the cortical bone covering the trabecular bone structure was damaged, the wire did show evidence of cutting through the spongy bone.

CONCLUSION

Metal pins (K-wires and Steinmann pins) are often used in orthopaedic surgery for (1) applying skeletal traction, (2) internal fixation of fractures and osteotomies and (3) the arthrodesis of the joints. Whether used for traction or for other purposes, the relationship between the pin diameter and the load which can be safely applied to the pin is often questioned. The factors limiting the amount of weight that can be safely applied to a pin include the potential damage to joints from excessive stretching, the strength of the pin, and the holding power of the bone.

The results of this study indicate that thin K-wires could be used successfully as traction pins. Excessive bending of these wires could be prevented by applying axial tension with the help of a Kirschner bow. The possibility of a pin cutting through bone is minimal if the cortical bone structure of the patient is normal. However, further *in vivo* study is necessary to ascertain if bone necrosis might occur due to excessive contract stress between the pin and the bone.

ACKNOWLEDGMENT

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RECOVERY OF DIAPHYSEAL BONE STRENGTH AFTER RIGID INTERNAL PLATE FIXATION

An Experimental Study in the Rabbit

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The course of the recovery from the unfavourable effects of a rigid internal fixation plate on the strength of diaphyseal bone, measured as the maximum torque capacity, has been studied in rabbit tibiae. Due attention was paid to the screw holes. On removal of the plate, which had been applied for 12 weeks without prior osteotomy, the bone had decreased in strength by approximately 50 per cent.

Following removal of the plate, the bone regained its normal strength after only 6 weeks. The regaining of strength proceeded in a significantly non-linear manner and in accordance with the logistic function

$$S = \frac{t}{a + b e^{-t}}$$

Key words bone adaptation, bone strength diaphyseal bone, internal fixation, internal fixation plates, recovery of bone strength

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Internal fixation by means of metal plates is a well-known and established method of fracture treatment, mainly due to the basic research work of the AO-group (The Association for the Study of Internal Fixation, Grenchen, Switzerland, Müller et al 1965). In a previous investigation (Strömberg & Fryman 1976b), the weakening effect of an internal fixation plate *per se* upon a diaphyseal bone was elucidated. It was stated that the presence of a diaphyseal bone fracture treated with internal plate fixation should not be considered as complete until the bone had regained its process of reconstruction and had regained its normal strength after the removal of the implants. The time required for the bone to regain its strength was not studied. The purpose of the present investigation was to clarify the time required for a rabbit tibia previously stabilized for 12 weeks by

means of a rigid internal fixation plate, type AOI (Müller et al 1970), to regain its normal strength, measured as the maximum torque capacity.

MATERIAL

Eighty-seven healthy adult rabbits (Swedish land race, weighing 3-5 kg) of both sexes were used and in 65 of them the effect of rigid internal fixation on the torsional strength of their tibiae was studied. Twenty-two animals were thus excluded because of complications arising from the anaesthesia, fractures and technical failures.

As stabilizing devices, internal fixation plates suitable for rabbit tibia were designed and manufactured in accordance with AOI internal fixation compression plates. They were made from stainless steel (ISI 316), measured 35 x 6 x 2 mm and had four screw holes. The plates could be regarded as rigid compared with the rabbit tibiae

The plates were fastened to the tibiae by means of four screws (type AOI) with a diameter of 2 mm and of sufficient length (10–15 mm) designed for cortical bone.

METHODS

The rabbits were divided into two main groups, group I and group II. Group I consisted of 26 rabbits. In these animals the weakening of the tibiae caused by the application of a rigid internal fixation plate was studied. In the 39 rabbits in group II the regaining of normal torsional strength after plate removal was studied.

The main groups were further divided into smaller sub-groups. Group I was thus divided into four sub-groups in which the torsional strength was measured 6, 8, 10 and 12 weeks after surgery.

In group II the internal fixation plates were left in place for 12 weeks causing weakening of the test bones. The plates were then removed and with the tibiae no longer stabilized the process of recovery of strength could begin. In this group comprising six sub-groups the maximum torque capacity of the tibiae was measured 1, 2, 3, 4, 5, 7.5 and 11 weeks after plate removal.

In agreement in maximum torque capacity between two tibiae of a related pair has been demonstrated in dogs (Stromberg & Dalén 1976a; Netz *et al.* 1978). In order to verify whether a corresponding agreement exists in the rabbit the tibiae of 10 rabbits were torsionally tested. The difference in torsional strength between the right (X_1) and the left (X_2) tibiae was calculated by the

$$\text{formula d } \frac{X_1 - X_2}{(X_1 + X_2) 0.5} \cdot 100$$

The results showed a significant ($P < 0.05$) uniformity of maximum torque capacity between related pairs of tibiae (Table 1). The mean value for the right tibia was 2.1 per cent lower than that for the left but this difference is not significant ($P < 0.05$). In the present investigation this justifies the use of one tibia of a related pair chosen at random as test bone and the other as control.

Operative procedures

After weighing the rabbits were anaesthetized with Mebumal vet[®] (ACO Solna, Sweden) diluted in physiological saline solution in a ratio of 1:3. Thirty-five mg per kg body weight corresponding to 15 mg/ml were administered intravenously and further doses were given during surgery if and when required. All operations were performed under strictly sterile conditions. A straight incision was made in the skin and fascia over the rabbit's tibia running from the distal

part of the knee to the level of the malleolus over the margo anterior tibiae. The lateral aspect of the tibia was exposed by retracting the tibialis anterior muscle. The plates were fastened to the tibia in accordance with the method described by the AO group (Mile 1970) and by means of the AOI small fragment instrument set (Synthes CH 4437, Waller, Switzerland) without any previous drilling. When the plates had been applied to both tibiae of an animal the plate from one of the tibiae was removed at random and the bone selected as the control. The screws were reinserted into their holes. The fasciae were sutured with catgut and non-absorbable sutures. All the rabbits both in group I and II had hitherto been treated in the same way. After 12 weeks however the rabbits were submitted to a second surgical operation and the plates were removed. The screws were reinserted into their holes and the skin and fascia sutured as in the previous operation.

Postoperative treatment

The postoperative course was uneventful; the animals were kept in cages large enough to permit normal exercise. They received adequate food and water and were observed daily. At the removal of the plates all treated bones were submitted to radiological examination in order to exclude any loosening of the implants (Fig. 1).

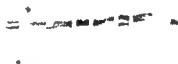


Figure 1 A rabbit tibia with an AOI fixation plate.

Sacrifice

The rabbits were sacrificed with lethal doses of Mebumal vet[®] given intravenously.

Bone preparation

Immediately after sacrifice both tibiae were dissected free of all soft tissue and connected to the femur and humerus bones. The tibiae were kept moist in physiological saline solution at a temperature of approximately 37°C until they were to be used for torsional strength.

1 Maximum torque capacity of the right and the left tibiae of 10 rabbits. The difference between the right and the left tibiae from the same animal is expressed as the percentage deviation from the mean of the two bones. The mean value for the right tibiae was 11.9 per cent lower than that for the left, but the difference is not significant ($P > 0.05$)

Rabbit no	Maximum torque capacity (Nm)		Percentage deviation
	Right tibia	Left tibia	
1	2.37	2.46	-1.9
2	1.91	1.95	-1.0
3	1.70	1.90	-5.5
4	2.66	2.33	+6.6
5	1.45	1.57	-4.0
6	2.28	2.08	+4.6
7	2.38	2.40	-0.4
8	2.61	2.36	+5.0
9	1.75	1.63	+3.6
10	2.33	2.31	+0.4

2 Maximum torque capacity, after plate removal, of rabbit tibiae to which rigid internal fixation plates had been applied for 6, 8, 10 and 12 weeks, and that of the paired control tibiae

Observation no	Maximum torque capacity (Nm)							
	6 weeks		8 weeks		10 weeks		12 weeks	
	Test tibia	Control tibia	Test tibia	Control tibia	Test tibia	Control tibia	Test tibia	Control tibia
1	2.39	3.64	2.72	3.44	2.17	3.67	1.64	4.64
2	2.53	4.11	2.58	3.14	1.65	2.14	1.88	4.98
3	2.63	2.73	2.54	2.84	1.23	2.47	2.58	3.48
4	1.90	3.66	1.85	2.95	0.80	2.07	1.73	3.75
5	2.46	3.32	1.40	2.78	3.09	3.24	1.07	1.69
6	3.50	2.96	1.20	2.47	1.91	3.80	0.96	2.51
7			2.76	2.99	2.27	2.45		

Material tests

The tibiae were tested within 30 minutes after sacrifice. The torsional strength of the bones was measured as the maximum torque capacity on a twist at 6° per second. The tests were performed by means of a test machine and in accordance with the method described by Berg & Dalen (1976a). The output signal from the test machine gave the torque which was recorded as a function of the deformation by a sensitive time-base recorder — a direct light ultra-violet beam oscillograph (Hofel, E. Siemens Halske AG, Henzestrasse 3520 Erlangen 2, FR Germany).

Sources of error

The experimental error of the torsional test is the largest source of error.

Calculations

The original data from the torsional tests are given in Nm and the figures are presented in Tables 2 and 4.

The mean percentage deviation in torsional strength between test and control bones after each time interval is calculated from the sum of the

Table 3 Means of the maximum torque capacity of rabbit tibiae affected by a rigid internal plate and of the paired control tibiae. The deviation of the mean torque capacity of the plated tibiae is expressed as a percentage of the corresponding value obtained from the control

Weeks after performed internal plate fixation	Mean of the maximum torque capacity (Nm)		Percentage deviation
	Test tibiae	Control tibiae	
6	2.56	3.40	-24.7
8	2.15	2.94	-26.9
10	1.87	2.83	-33.9
12	1.64	3.51	-53.3

observations in the test and control bones. The data thus calculated are also given in Tables 3 and 5.

Statistical methods

Conventional statistical methods were used to estimate the mean values and standard deviations. Statistical significance of the difference between stabilized and non-stabilized bones was calculated by means of the *t*-test for paired and independent samples.

In order to clarify the progress of return of strength of the previously plated bones, measured as maximum torque capacity, two regressions were performed, a non-linear regression in accordance with a logistic function where $\hat{y} = \frac{t}{a + bt}$ and a linear one where y equals $a + bt$. The sum of residuals in the former case was compared statistically with the residual sum of squares of the latter.

$P < 0.05$ was considered as non-significant.

weeks, thus causing a 53.3 per cent reduction in maximum torque capacity showed 1, 4, 5, 7, 5 and 10 weeks after removal of plates (and reinsertion of the screws into the holes).

- a significant ($P < 0.05$) increase in maximum torque capacity;
- a significantly ($P < 0.05$) non-recovery of strength, in accordance with the logistic function $\hat{y} = \frac{t}{a + bt}$ measured as maximum torque capacity;
- a significantly ($P < 0.05$) more return of full torsional strength in the bone, measured as maximum torque capacity, compared with the development of the corresponding weakening in the bone due to the application of the internal fixation plate.

RESULTS

I Compared with the corresponding control bone, the rabbit tibia, stabilized according to the AO-method by means of a rigid internal fixation plate for 6, 8, 10 and 12 weeks, displayed after removal of the implants, but with the screws reinserted into the bone

a significant ($P < 0.05$), progressive reduction in maximum torque capacity with increasing duration of plate fixation.

II Rabbit tibiae, stabilized with a rigid internal fixation plate, type AOI, for 12

DISCUSSION

In amending their original recommendation concerning the time for plate removal to 6 months (Muller et al 1965) to 18 months (Muller et al 1970) after an internal fixation procedure, in order to diminish the risk of refractures the AO group took the time into consideration. It is difficult to decide clinically whether or not a fracture has healed when it is treated with a rigid internal fixation plate producing compression at the fracture ends in accordance with the method (Richon et al 1967).

Maximum torque capacity (Nm)

Observation no	1 week		2 weeks		3 weeks		4.5 weeks		7.5 weeks		10 weeks	
	Test tibia	Control tibia	Test tibia	Control tibia	Test tibia	Control tibia	Test tibia	Control tibia	Test tibia	Control tibia	Test tibia	Control tibia
1	2.47	2.74	1.37	1.81	6.34	5.74	4.92	4.96	3.52	3.22	5.39	5.07
2	0.95	1.87	1.19	1.56	3.10	5.91	4.52	5.10	2.84	2.38	5.53	3.88
3	1.87	2.59	1.18	2.51	4.97	3.95	4.77	6.25	4.14	3.75	4.65	4.60
4	2.60	3.22	1.58	2.47	3.98	4.15	5.21	5.21	4.34	4.80	3.29	3.80
5	1.92	2.78	1.41	2.52	1.52	2.51	3.41	4.04	2.98	2.93	3.60	3.66
6			3.44	6.71	1.84	2.86	3.39	3.17				
7			4.60	4.22	3.95	5.21						
8			2.74	2.44	3.88	4.10						
9			1.95	2.33	4.44	4.57						

Table 5. Means of the maximum torque capacity of rabbit tibiae, previously plated for 12 weeks and tested 1, 2, 3, 4, 5, 7, 5 and 10 weeks after plate removal, and of the paired control tibiae. The deviation of the strength of the previously plated tibiae is expressed as a percentage of the corresponding value obtained from the control tibiae

Weeks after plate removal	Mean of the maximum torque capacity (Nm)		Percentage deviation
	Test tibiae	Control tibiae	
1	1.96	2.64	25.8
2	2.16	2.95	26.8
3	3.78	4.33	12.7
4.5	4.37	4.79	8.8
7.5	3.56	3.42	4.1
10	4.49	4.20	6.9

A rigid internal fixation plate fastened to the fractured bone by means of screws will together with the screws and bone form a mechanical joint, rigid compared with the unplated bone. There will thus be an increased stiffness in the load bearing construction and consequently a decreased stress and strain concentration in the bone component of the thus formed mechanical joint as compared with that in the unplated bone. The increased stiffness is equivalent to the decreased deformation produced by a certain load (Netz et al 1978).

Bone has the ability to adapt itself to functional load demands (Wolff 1892). The mechanism underlying this property of bone is not yet fully understood. It has been demonstrated that the stress and strain concentration is of crucial importance for bone metabolism and reconstructive activity (Bassett 1971, Pauwels 1973).

The application of a rigid internal fixation plate to a diaphyseal bone will cause an immediate change in the load situation. Due to the stiffness of the plate, which compared with the bone can be regarded as rigid, the load carried by the bone part of the mechanical joint is almost negligible. The decreased stimulation of the anabolic bone metabolism will cause an atrophy of the cortical bone resulting in reduced strength (Strömberg & Dalen 1978).

The gradual atrophy will probably not affect the load situation significantly, as the plate will carry almost all the load as long as the mechanical joint exists. The cortical atrophy and the concomitant weakening of the bone should thus theoretically develop at a constant speed.

In the present study, however, we could not verify the presumed linear development of the weakening due to the plate. We consider that this is not possible with the present experimental model.

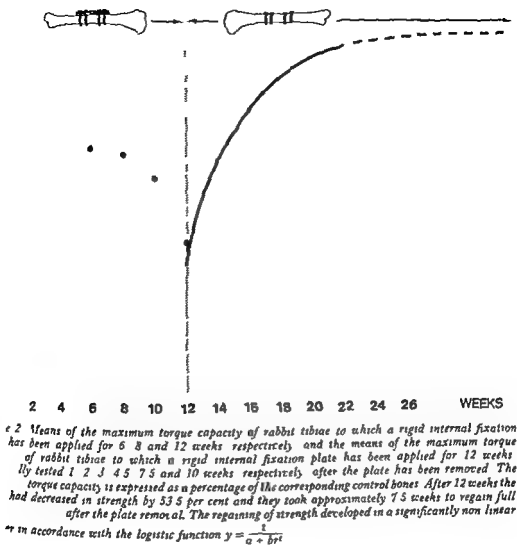
Burstein and co-workers (1972) showed that rabbit diaphyseal bone with an inserted screw, similar to the one used in the present study, will regain its torsional strength after 8 weeks. We thus did not consider it

appropriate to study the weakening of the plated bone during the first 6 weeks, the interaction between the screws and the holes on one side and the plate on the other.

When the internal fixation plate was removed after 12 weeks a sudden new situation occurred in the bones. It is reasonable to assume that the weakened rabbit tibiae had undergone a kind of atrophy uniformly throughout the bone. Previously stabilized cortical bone (see Strömberg & Dalen 1978, Slatys et al 1978). As the animals started to bear weight on the previously plated bones an enlarged stress and strain concentration arose. Consequently there was an increased stimulation of bone-forming cells to produce bone to replace the load-bearing function of the plates. The bone adapts itself in this way to the new functional and physiological demands in accordance with Wolff's law.

It is the lack of cortical bone in the previously stabilized diaphyseal section, in combination with the increased load on the segment to a normal level, which causes increased stress and strain. The volume of bone in the atrophied cortex when the plate is removed. Consequently will stimulate anabolic bone metabolism resulting in an increased cortical bone formation. However, as the bone gradually recovers from its atrophy, i.e. the amount of bone material approaches a normal level, there will be a concomitant decrease in the stress and strain concentration resulting in a simultaneous and gradual decrease in stimulation of the bone-forming cells. This is confirmed by the present results (Fig. 1). The readaption process is thus non-linear and in accordance with a logistic function, therefore in contrast to theoretical expectations concerning the development of the corresponding weakening of the bone.

The time required by the bone to regain its strength was, in the present study, 8 weeks. The time required by the bone to adapt to the new load situation due to the plate, i.e. the



he weakening process. The cause of this discrepancy is not yet fully understood.

treatment of a fractured diaphyseal with a rigid internal fixation plate as by the AO-group must not be

complete until a certain period elapsed after the removal of the plate and bone has thus regained its normal

(cf. Stromberg & Dalen 1976b). We tempted to recommend that the length of period should be at least half that of the previous period of internal plate fixation. On basis of the present results, we are

inclined to postulate that the unfractured part of the previously stabilized bone needs that amount of time after removal of the plate to complete its process of reconstruction and to regain its normal mechanical strength.

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ERIAL REACTION OF DIAPHYSEAL BONE ER TORSION

Experimental Study on Dogs

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The formation of microcracks in entire canine diaphyseal bones under torsional loads was studied. The acoustic emission technique was used to register the stress waves which were generated in the bones by crack

diaphyseal canine bone material

Key words acoustic emission, diaphyseal bone, elastic properties, experimental fractures, mechanical properties of diaphyseal bone, torsional testing, ultrasonic sound

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mechanical behaviour of diaphyseal bone applied loads has been the subject of considerable interest in recent decades. One of loading compact bone is assumed to be elastic deformation in macroscopical parts of bone associated with dislocation on and motion (Currey 1970, Burstein et al 1972, 1973). Authors (Robertson et al 1978) recently found that the size of the plastic deformation around a crack tip in bovine bone is smaller than 0.02 mm. This result indicates that diaphyseal bone deforms only within almost microscopical

Microcracks have been observed in cortical bone by many authors (Frost 1960, Frost et al 1961, Pope & Outwater 1972, Carter & Hayes 1977a). The formation of microcracks is a phenomenon which reconciles the decreasing stiffness of a body and the elastic-cracking behaviour of the material (Broek 1974).

This raises the question as to the relationship between the non-linear deformation of entire diaphyseal bone (Netz et al 1979) and the appearance of microcracks in the bone material, a topic on which the present work was focused.

MATERIAL

The test material consisted of nine fresh diaphyseal bones (tibiae and femora) with closed epiphyseal lines from healthy long legged dogs of varying breeds and of both sexes.

Carter & Hayes (1977a, b) have shown that the stiffness of compact bone specimens in flexural and in tension fatigue loading in torsion of the entire bone is accompanied by decreasing bone stiffness (Netz et al 1979).

METHODS AND TEST EQUIPMENT

Torque

The torsion test equipment, described by Strömberg & Dalén (1976) was used to twist the bones to fracture. As the maximum torque capacity of diaphyseal bones is independent of the twist rate in the range 3–12° per second (Strömberg & Dalén 1976) the twist rate for the present investigation was fixed at 6° per second.

Acoustic emission

The most common types of mechanical behaviour of materials under applied loads are deformation and fracture. Many other phenomena, e.g. dislocation generation and motion, crack formation and/or growth, may also occur in a material. Acoustic detection of phenomena in materials is conveniently called acoustic emission or A E.

A E is a non-destructive testing tool, used in the field of strength of materials and solid mechanics (Dunegan & Harris 1969). The A E in the loaded test body is detected by a sensing lead-zirconate-titanate (PZT) transducer. The

transducer converts low level stress or electrical signals. The signals are filtered, processed and registered on a recorder.

The character of stress waves generated by dislocation generation differs from that of waves from cracking. Briefly, processes associated with dislocations are uniform, those associated with cracking have a sudden and sharp appearance (Tetelman 1971).

The A E technique thus permits study of the generating process. Distinction of different types of stress waves is a delicate matter and must be left to experts with considerable experience in the field.

In the present experiments a sensing (type D 140 A Dunegan/Endevco, Capistrano, Calif., USA) connected amplifier, filter and processor unit recorder and a reset clock was used (202, 301, 402 respectively Dun (Figure 1)).

TEST PROCEDURE

The test bones were attached to the machine grips as described by Strömberg &

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AD 07

FIGURE 1

FIGURE 1

Figure 1 Simplified block diagram of acoustic emission (A E) system

The A.E. transducer was applied on the surface (Figure 2). Great care was taken to reduce transmission losses of the acoustic signal. The A.E. within the range 140–500 kHz was registered (maximum sensitivity at 220 kHz). A reset clock was provided with a pulse selector which gave a choice of time intervals. The A.E. counts were registered audibly or with time resolution for the prior analysis. The time intervals used were 0.1 and 0.2

seconds. The torsional deformation was divided into intervals of 1.2 degrees corresponding to 0.2 seconds. The point (B Figure 3) on the recorded torque-twist curves where the curve turned non linear was determined. The deformation interval containing point B was considered as interval zero and called the "turnover interval". The deformation intervals in the linear range were indicated with negative numerals down to zero twist and the deformation intervals in the non linear range with positive numerals up to ultimate failure of the bone.

A.E. signals characteristic of crack formation and/or growth were nullified.

Torque (Nm)

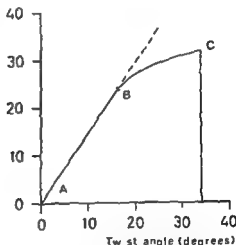


Figure 3 Recorded torque-twist curve. Torque is given in newtonmeters (Nm) and the twist in degrees. A is the point of onset of torque. A-B is the linear part of the curve and B-C is the non linear part prior to final fracture of the bone at C.

RESULTS

At all torsional tests a torque-twist curve was recorded comprising two characteristic parts (Figure 3) a linear starting from zero load which at a critical point turned to a non linear phase prior to the final fracture.

The bones fractured within the range ~30–50 per cent of the total twist (Table 1).

A.E. signals characteristic of crack formation and/or growth occurred in bursts when audibly checked and on the recordings

2 The sensing transducer for the acoustic emission (A.E.) recordings firmly attached to the surface of a diaphyseal canine bone prior to all testing.

For testing the torsion test machine and A.E. equipment were calibrated. The location of the A.E. signals was adjusted to reduce extraneous noise e.g. from the test machine and the total amplification used was 40 dB.

During testing the bones were twisted inwards and both torque and A.E. counts were continuously plotted as functions of applied torque on the multichannel light beam recorder (Lette 5651 ABEM Bromma, Sweden). Furthermore the A.E. counts were transmitted to an audible range by means of an amplifier (type 702, Dunegan/Endevco). During the performance of the A.E. recordings and in the following analysis of the findings obtained assistance was obtained from Stockholm, Sweden.

CONCLUSIONS

Torque was given in newtonmeters and the twist in degrees.

Table 1 Maximum torque capacity (newtonmeters Nm) of nine fresh diaphyseal canine bones during

Bone No	Maximum torque capacity (Nm)	The twist in the linear phase in per cent of the total twist
1	22.2	38
2	27.2	51
3	29.8	40
4	40.2	35
5	40.4	48
6	27.0	43
7	28.1	32
8	30.1	34
9	29.8	40

had a step-wise and sharp character with an increased frequency towards the ultimate failure of the bone.

Signals characteristic of crack formation and/or growth were registered solely in the

non-linear range of the torque-twist relationship and compared with the twist in the linear range the difference was significant ($P < 0.01$) (Figure 4).

In recordings obtained when the transducer was close to the fracture propagation path appearance of the A E signals coincided with the onset of the non linear deformation on the torque-twist curve (bones Nos. 1, 2, 4, 5). A E signals occurred somewhat later in the non linear deformation when the transducer was away from the fracture propagation path (bones Nos. 3 & 3 & 4).

In the tests when the transducer was close to the fracture propagation path the stress waves were more intense. It was possible to determine the exact relationship between the intensity and the distance between the transducer to the fracture path, the smaller the distance the more intense the signals.

Examples of two recordings are given in Figures 5 and 6.

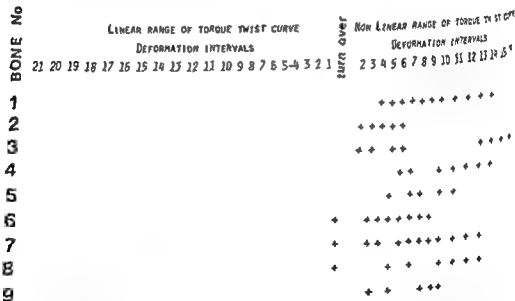


Figure 4 Acoustic emission signals characteristic of crack formation and/or growth during loading until final fracture of nine fresh diaphyseal canine bones. The registered deformation was divided into intervals of 1.2 degrees. The 'turnover interval' is the deformation interval when the torque-twist curve turns non linear. The turnover interval was fixed at zero and numerals indicate intervals within the non linear range. Negative numerals indicate intervals in the linear range down to zero twist. Acoustic emission signals characteristic of crack formation and growth (marked with + signs) were registered solely in the non linear range of the torque-twist

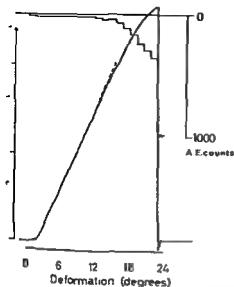


Figure 5 A recording of the simultaneous registration of the torque-twist relationship and the acoustic emission (AE) signals of a canine diaphyseal bone (test bone No 6). The time resolution of this recording is 0.2 seconds i.e. the registered AE counts represent the foregoing 0.2 second time-interval. Torque is given in newtonmeters (Nm) and twist in degrees.

Concomitant with the torque-twist curve turning non linear, the AE counts increase towards final fracture of the bone.

DISCUSSION

Cracks in diaphyseal bones were first reported by Rutishauser & Majno (1951) and their presence was later confirmed by Frost (1961) and Frost et al (1961). Recently, Carter & Hayes (1977a, b) observed microcracks in flexural and in tension fatigue tests of compact bones. On this basis they concluded that "the postyield regime of bone is not evidence of bone brittleness (as suggested by Burstein et al 1961), but the result of diffuse structural damage" (Carter & Hayes 1977b). Loading of bone and of entire diaphyseal bones reduces their stiffness (Carter & Hayes 1977a, b; Netz et al 1979). The reduction of stiffness is sufficient to explain the non-linearity of the load-deformation relationship of entire

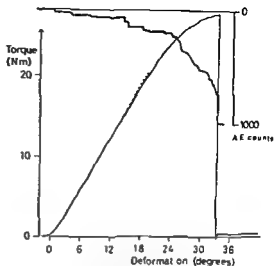


Figure 6 A recording of the simultaneous registration of the torque-twist relationship and the acoustic emission (AE) signals of a canine diaphyseal bone (test bone No 7). The AE counts are registered momentarily as a summation curve. Torque is given in newtonmeters (Nm) and twist in degrees.

Concomitant with the torque-twist curve turning non linear, the AE counts increase step-wise towards final fracture of the bone.

diaphyseal bone. Strong indications that the non-linearity is essentially due to microcracking were put forward by Carter & Hayes (1977b) and Netz et al (1979).

The AE technique used in the present study allows detection of material events in a diaphyseal bone twisted to fracture. An interesting feature is that the pattern of the AE signals depends to a large extent upon the generating process, e.g. the character of stress waves generated by dislocation generation and motion differs from that of stress waves from cracking. A typical feature is dissipation and redistribution of the energy stored in the material. The redistribution of energy is associated with propagation of stress waves in the material, which lend themselves to detection with acoustic techniques. The acoustic activity during deformation of the bones was registered in order to identify its origin.

In the present study, the A E signals had a step-wise, sharp character and an increased frequency towards the ultimate fracture, characteristic of crack formation and/or growth (Tetelman 1971).

Plastic deformation in an axially twisted cylinder engages a uniformly distributed large volume of material and the observed frequency of A E counts is fairly independent of the location of the transducer (Mendelson 1968). In our test there was notable variation of the frequency of the A E counts between the bones. The registrations with fewer A E counts were obtained when the transducer was placed away from the final fracture propagation path. Previously, tests have shown that the ultrasonic sounds in compact bone are severely damped when propagating in other directions than the long axis of the bone (Sandberg 1978). This is assumed to be an effect of the internal architecture and material distribution of the bone, i.e. the orientation of the osteons in the longitudinal direction of the diaphyseal bone (Pope & Outwater 1974).

Diaphyseal bone is made up of heterogeneous materials. The distribution of bone material and the distribution of inhomogeneities vary in different parts of the bone and with time. The area of least resistance, where the fracture path will propagate, is unpredictable (Currey 1962). In the registrations where less A E counts characteristic of cracking occurred there were no signals typical of dislocation generation either. A E signals characteristic of formation and/or growth of cracks were registered only in the non linear range of the torque-twist curve. Elastic-plastic and elastic-cracking materials may in fact exhibit identical non linear loading relationships although the nature of the material behaviour is totally different in the two cases. The mode of behaviour of a material can thus not be uncritically inferred from a load-deformation relationship.

Thus, by means of the A E technique we have registered A E signals which are associated with crack formation and/or growth, during non linear deformation of

twisted diaphyseal bone. We consider the present results to be significant evidence in favour of our previous postulation that linear deformation of diaphyseal bone prior to ultimate failure is due to a gradual formation of microcracks. The assumption that the entire canine diaphyseal bone at all times behaves in accordance with a cracking material is thus supported.

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INFLUENCE OF A LOCAL INJECTION OF CORTISOL ON THE MECHANICAL PROPERTIES OF TENDONS AND LIGAMENTS AND THE INDIRECT EFFECT ON SKIN

OLUF
LUND

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The effects of local cortisol treatment on the mechanical properties of muscle tendon and ligament in rats were studied. In addition to the local effects, possible systemic effects as reflected in the properties of the skin, remote from the site of the injection, were investigated. Two groups of rats were given cortisol injections, 20 mg/kg, every third day for 24 days. In one of the groups the injections were given bilaterally around the peroneal tendons and in the other they were given into both knee joint cavities. Specimens from the peroneal tendons, the posterior cruciate ligament with bone attachments, and strips of skin from the dorsum, were tested in a materials testing machine. The local treatment resulted in increased "tensile strength" of the peroneus brevis tendon and increased maximum load and stiffness of the peroneus longus tendon with no change in the collagen content in any of the samples. The posterior cruciate ligament always broke at one of the two sites of attachment to the bone and the maximum load value at these points was decreased after local cortisol treatment. The systemic effects of this local cortisol treatment on the skin were decreased thickness and fat content, increased collagen concentration and higher "tensile strength" and failure energy. From this study it is concluded that local cortisol injections for 24 days increase the strength and stiffness of muscle tendons, but decrease the strength of the bone attachments of ligaments. This treatment also results in a systemic effect which shows itself as increased strength of the skin remote from the site of the injections.

Key words: biomechanics, bone, collagen, hydrocortisone, ligaments, tendons

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The effect of muscle tendons has been studied to glucocorticoid treatment and rupture of the Achilles tendons in rats on oral glucocorticoid therapy has been reported by Cowan & Alexander (1961), Smail (1961) and Melmed (1965). The effect after local glucocorticoid treatment has also been reported. Local injections into the Achilles tendon (Lee 1957) and

the patellar tendon (Ismail et al 1969) have thus resulted in rupture of the tendinous tissue.

A previous study on the influence of systemic prednisone treatment on the biomechanical properties of rabbit muscle tendons (Oxlund et al 1978) showed that treatment for 14 days (2 mg/kg) resulted in increased tensile strength and stiffness of the

Table 1 Body weights

	n	At start of injections	At sacrifice
Intact control	8	418 (40)	436 (38)
Peroneal tendons			
Saline injected	9	422 (39)	432 (32)
Cortisol injected	6	432 (36)	305*** (31)
Posterior cruciate ligament			
Saline injected	7	424 (44)	419 (42)
Cortisol injected	7	408 (25)	279*** (22)

Mean with s.d. in parenthesis

***2P < 0.001 against saline injected control

Table 2 Water and collagen content of muscle tendons

	Water content (per cent)	Collagen content (mg./mm)	
		Tendon of peroneus tertius and quartus	Tendon of peroneus long
control	56.7 (1.5)	0.22 (0.02)	0.14 (0.01)
injected	61.7*	0.21 (0.01)	0.14 (0.01)
control injected	59.1 (0.8)	0.18 (0.01)	0.13 (0.01)

* with s.e. mean in parenthesis
0.05 against intact control*Strain parameters*

g collagen per mm specimen length

* strain at maximum "stress" (Same

max
maximum "stress" - ultimate "tensile strength"elastic stiffness - tangent of the angle
in the linear region of the "stress"-strain
and the x-axis* energy (A) energy measured as the area
between the "stress"-strain curve and the x-
axis to the point of breaking* statistical analysis the data were analyzed
normal distribution using the test of
Kolmogorov-Smirnow, the G1-test and the G2-
test for homogeneity of variances the F-max-test (Sokal & Rohlf 1969) Group means were
thereafter compared by Student's *t* test and
differences were considered significant if
2P < 0.05

RESULTS

No differences in the body weights (Table 1) were observed between the groups at the start of injections. At sacrifice the body weights of the cortisol injected rats had decreased, while no such effect occurred in the other groups. The saline injections did not change the biomechanical properties of tendons, ligament or skin.

Table 3 'Stress'-strain and load strain data from the muscle tendons

		$\epsilon_{\sigma_{\max}}$	σ_{\max}	$\tan \alpha$	Failure energy (A)	F_{\max}	$\tan \beta$	F_{fail}
	n	(-)	(N/UC)	(N/UC)	(N/UC)	(N)	(N)	(N)
Peroneus brevis tendon								
Intact control	8	0.23 (0.01)	150 (8)	1063 (114)	2042 (170)	32.3 (1.3)	277 (18)	4.1 (0.5)
Saline injected control	9	0.21 (0.01)	157 (7)	1219 (72)	1845 (151)	32.6 (1.7)	251 (9)	3.8 (0.4)
Cortisol injected	6	0.22 (0.02)	195* (15)	1513 (128)	2512 (357)	35.2 (1.4)	274 (19)	4.1 (0.5)
Peroneus longus tendon								
Intact control	7	0.19 (0.01)	193 (16)	1389 (140)	2076 (139)	26.2 (1.7)	188 (16)	3.1 (0.4)
Saline injected control	9	0.17 (0.01)	177 (15)	1422 (103)	1762 (185)	24.2 (1.4)	198 (12)	3.1 (0.4)
Cortisol injected	6	0.18 (0.01)	222 (17)	1850* (126)	2220 (196)	28.6* (1.3)	240 (16)	3.4 (0.4)

Mean with s.e. mean in parenthesis

N=newton

UC=unit collagen; i.e. mg collagen per mm specimen length

*2P<0.05 against saline injected control

Local effects of cortisol injections

Tendons The water content of the tendons of peroneus tertius and quartus (Table 2) was increased after saline injections whereas no change occurred after cortisol treatment. No differences were observed between the groups with regard to the collagen content of the peroneus brevis and longus tendons. The maximum "stress" value for the cortisol treated peroneus brevis tendons was increased compared with tendons from the saline control group (Table 3). Figure 1 shows the "stress"-strain diagrams. For the peroneus longus tendons (Table 3) the elastic stiffness ($\tan \alpha$) and maximum load value were increased for the cortisol treated group compared with the saline injected control group.

Ligament For the posterior cruciate ligament the maximum load values of cortisol treated ligaments (16.1 ± 1.6 newton, mean \pm s.e. mean) were decreased ($2P < 0.05$) compared with those of saline injected controls (22.8 ± 2.2 newton) (Figure 2). The failure of the bone-ligament bone specimens took place at one of the two bone attachments.

Systemic effects of local cortisol injections

Skin The thickness of skin (Table 4) from rats injected with cortisol around the peroneal tendons and from those injected into the knee joint cavity was decreased. Differences in the water content of the skin (Table 4) were observed between the groups. The collagen concentration of skin (Table 4) was increased and the amount of subcutaneous fat was decreased for cortisol treated rats compared with saline injected groups. In mechanical testing of skin strips from the peroneal group injected with cortisol around the tendons, the maximum load (mean \pm s.e. mean) resulted in increased ($2P < 0.01$) maximum load (0.70 ± 0.02) and maximum load (51.0 \pm 3.0 newton) compared with the saline injected control group (0.61 ± 0.02 and 37.6 \pm 3.0 newton respectively). Of the "stress"-strain diagrams the maximum "stress" (stress/area) (2152 \pm 101 newton/mg/mm) and the failure stress (2152 \pm 101 newton/mg/mm) for the cortisol treated group were increased ($2P < 0.001$) compared with the saline control group (47.2 \pm 2.6 newton/mg/mm and 1386 \pm 79 newton/mg/mm, respectively).

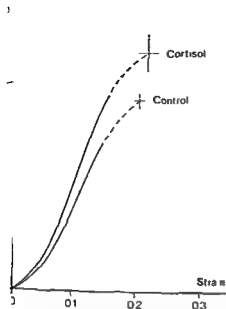


Figure 1 "Stress"-strain diagrams for the posterior cruciate ligament of rats: Control saline injected into the knee joint cavities; Cortisol 20 mg/kg injected into the knee joint cavities (s.e. mean for the coordinates of the maximum point indicated by bars)

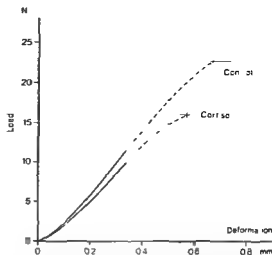


Figure 2 Load-deformation diagrams from the posterior cruciate ligament of rats: Control saline injected into the knee joint cavities; Cortisol 20 mg/kg injected into the knee joint cavities (s.e. mean for the coordinates of the maximum point indicated by bars)

Table 4 Thickness and composition of skin

	Thickness (mm)	Water content (per cent)	Collagen concentration (per cent of DDW)	Fat (per cent of DW)
control	1.91 (0.05)	57.6 (0.3)	76.8 (1.9)	16.2 (1.3)
in around tendons				
s.e. injected	1.89 (0.06)	58.1 (0.5)	75.8 (1.0)	13.9 (1.5)
cortisol injected	1.34*** (0.03)	56.8 (0.4)	83.6*** (1.3)	6.1*** (0.6)
in into knee joints				
s.e. injected	1.91 (0.05)	57.3 (0.4)	75.9 (2.1)	17.2 (1.8)
cortisol injected	1.39*** (0.06)	57.1 (0.4)	86.5*** (1.8)	6.0*** (0.9)

s.e. with s.e. mean in parenthesis

* < 0.01 against saline injected control

** < 0.001 against saline injected control

by weight

by dry defatted weight

N/UC

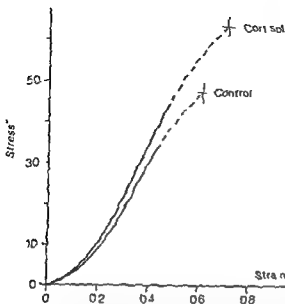


Figure 3 "Stress"-strain diagrams for skin. Control saline injected around the tendons. Cortisol 20 mg/kg around the tendons (i.e. mean for the coordinates of the maximum point indicated by bars)

(Figure 3) The mechanical parameters of skin strips from the group injected with cortisol into the knee joint cavity showed similar significant differences when compared with those of its control group.

DISCUSSION

Glucocorticoids are commonly used in the treatment of tendon and joint injuries. It has been suggested that this treatment may adversely affect the tendons and cause actual ruptures. The present study was carried out to elucidate this question. Local cortisol treatment for 24 days increased the strength and stiffness of muscle tendons with no change in their collagen content. This is in agreement with Mackie et al (1974) who injected the extensor digitorum communis tendons of rabbits with either a suspension of betamethasone sodium phosphate or betamethasone acetate (0.1 mg/kg) twice a week for 35 days, and found reduced tendon weight and increased maximum stress values,

whereas the stiffness of the tendons was influenced by the treatment. Philip et al (1974) studied the effect of prednisolone injections into rabbit tendons but found no influence of treatment on the mechanical properties of the ligament. However, the hormone was injected into the patellar tendon of the one rabbit and the other side was used as the control. The possible systemic effect of the injection may therefore have influenced the control. The effects of unilateral prednisolone treatment for 2 weeks on the mechanical properties of rabbit tendons (Oxlund et al) were increased "tensile strength" and "energy", i.e. in agreement with the results of the present study.

After cortisol injection into the joint cavity the strength of the cruciate ligament, measured as the maximum load of the bone-ligament unit, decreased. This experimental result is different from that of the study by Philip et al (1974) where the clamps were fastened directly to the tendon specimens. In the case of ligaments the condyles of the femur were mounted in the clamps and the bone as well as its bone attachments were included. Here the failure of the specimen takes place at one of the two bone attachments. Glucocorticoids inhibit the synthesis of collagen (Kuhn et al 1964, Kivimäki et al 1965, Manthorpe et al 1974) and the effect of glucocorticoids on bone are also consistent with an antianabolic action. Glucocorticoids may increase osteoclastic resorption and result in osteoporosis. The decreased mineralization is secondary to the increased bone resorption (Silberberg 1971, Simmons 1971). The turnover of collagen in bone is much higher than in tendon and therefore probably higher in bone than in ligament. Gander (1960) estimated the turnover time of collagen in bone to be 4 and 40 days for a fast and slow compartment, respectively, and in tendon to be more than 110 days. Therefore it may be hypothesized that the inhibition of collagen synthesis and the increase in

ism in bone during the 24 days of treatment was sufficient to impair the strength of the bone attachments of the tendons. The present study the time period of local treatment of the experimental animals was 24 days. In the clinical reports cited the rupture through the substance of the tendons the patients had been treated with glucocorticoids for months or years (Dowar & Alexander 1961, Lee 1961, 1961 and Melmed 1965). In these studies the inhibited synthesis of collagen had been present for a much longer time period and may have resulted in a decreased collagen content and weakening of the tendons. In the experiments, including mechanical testing of muscle tendons after long-term treatment, are needed to clarify this problem. Further studies of possible universal effects may be by the local cortisol treatment. The pronounced changes in skin. The decreased "tensile strength" and failure of the dorsal skin are in agreement with the findings (Vogel 1974, Oxlund et al 1974). The cortisol preparation used was a 1% suspension of hydrocortisone in saline commonly used for local injections in clinical practice. The dose in the present study (20 mg/kg every 3rd day) was higher than doses commonly used in glucocorticoid treatment of tendon and joint injuries in man. Differences between the effects of the predominant corticosteroid used in the present study and in sensitivity of cells and their response systems, however, make it difficult to compare the doses used in animal experiments to those used in clinical practice. Kivirikko et al (1964) studied the incorporation of ^{14}C glycine into rat skin collagen and found that the conversion of soluble to insoluble collagen was accelerated after 9 days of prednisone treatment. The synthesis of collagen was retarded, neutral salt soluble collagen decreased, while the insoluble and total collagen was increased. Kivirikko et al (1964) also found that cortisone had an inhibitory effect on the formation of soluble collagen but found no effect on the catabolism

of the insoluble collagen of rat skin. In the present study it was found that cortisol increased the strength of muscle tendons and skin. Both load-strain and "stress"-strain parameters were increased. "Stress"-strain parameters are load-strain parameters normalized to the collagen content of specimens, i.e. "functional cross-sectional area". The load-strain parameters are thus dependent on qualitative and quantitative changes such as thickness and width of specimens, while "stress"-strain parameters are dependent only upon qualitative changes in the tissue. It may therefore be suggested that the cortisol induced increase in the strength of muscle tendon and skin are caused at least partly by an increased stability of the collagenous fibres. When the treatment is continued over longer time periods (months or years) and the dose of glucocorticoid is high the inhibited collagen synthesis may gradually result in a marked reduction of the collagen content. This can weaken the tissue even though the cross-linking is increased and explain the findings in clinical reports. The shorter the turnover time of the tissue the sooner the impairment of its strength may take place as a result of inhibited collagen synthesis during cortisol treatment. On the other hand, if the treatment time is short compared with the turnover time of the tissue, the increased stability may compensate for the decreased synthesis of collagen maintaining or even increasing the strength of the tissue.

From this it can be concluded that local cortisol injections for 24 days increase the strength and stiffness of muscle tendons, but decrease the strength of the bone attachments of ligaments. This treatment also results in a systemic effect shown in this study as an increased strength of skin.

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THE PERIPHERAL VASCULAR DETERIORATION IN SCLERODERMA

A Report

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A report of a case of long standing Scleroderma (Progressive Systemic Sclerosis) is presented to emphasize the severe consequences of vascular compromise in the hand. The disease process is reviewed and is illustrated by the arteriographic findings in this patient.

Key words: arteriography, collagen disorder, hand, Progressive Systemic Sclerosis, Scleroderma.

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The following case of Scleroderma with involvement of both hands is presented in order to demonstrate the severity of peripheral vascular damage.

REPORT

A 61-year-old right handed female experienced a long standing phenomenon of both hands at the age of 40. Within several years the etiology of this condition became obvious when she developed Raynaud's phenomenon. An esophagram and skin biopsy were consistent with Scleroderma or Progressive Systemic Sclerosis.

In subsequent years, treatment included digital sympathectomy, stellate ganglion blocks and a right thoracic sympathectomy with no appreciable improvement in the peripheral circulation. Numerous amputations were necessary because of infarctions involving the digits of both hands. Hyperbaric oxygenation was tried during one amputation in an attempt to facilitate soft tissue healing but to no avail. Over a period of 10 years, multiple partial amputations of the right hand were necessary due to gangrene of the digits. The left hand was essentially spared (Figure 1).



Figure 1 The hands of a 61 year old female with Scleroderma

Within the year prior to this report the circulation to her left hand deteriorated rapidly. The thumb together with both the index and middle fingers became gangrenous, requiring amputation. Subsequently, the ring and little fingers, the only remaining digits, also became gangrenous, together with necrosis of the skin over the thumb stump (Figure 2).

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3 The severity of the vascular damage treated by arteriography



Figure 4 The vascular pattern in a normal hand

faintly visible. The superficial arch did communicate with the radial artery and was complete absence of vessels in the ring and little fingers. The vascular pattern in a normal hand serves as a vivid contrast (Figure 4).

MARY

A report of long standing scleroderma is presented to emphasize the severe consequences of obliteration of the peripheral vessels. The progressive deterioration of circulation in spite of vasodilators, stellate ganglion blocks, surgical sympathectomy, and hyperbaric oxygenation is demonstrated. Arteriography graphically illustrates the normal arterial pattern in the surgical specimens. The reluctance in using the pneumatic tourniquet control during surgical procedures and amputations is obvious. Without tourniquet control, further

vascular damage and poor healing may occur. The role of elective surgery in patients with Scleroderma and vascular impairment is minimal. Diagnostic arteriograms reported to be commonly employed in the investigation of patients with Scleroderma in some institutions would appear to be hazardous since they may further compromise a diseased vascular system.

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INTERFASCICULAR TRANSPLANTATION OF MEDIAN NERVE INJURIES

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Twenty four patients operated upon within a 3 year period for complete median nerve transection using the microsurgical interfascicular transplantation technique were examined after a minimum of 3 years' observation. Functional motoricity (M3 or higher) was achieved by 83 per cent. With the exception of one patient, all achieved protective tactile sensibility (96 per cent). The results were best for distal lesions in children and youths. The outcome was just as satisfactory as that attained with epineurial suture carried out under ideal conditions. The method was found to be superior to epineurial end-to-end suture in cases of nerve defects longer than 2.5 cm.

Key words: interfascicular transplantation, median nerve, microsurgery, nerve injuries, peripheral nerves

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Formation of scar tissue in the suture line of a transected nerve restricts axonal regeneration. Millesi et al (1972 a, b) and Wallenborn (1972) demonstrated, in experimental animal studies, that this scar was mainly formed by the epineurium and that it increased with tension in the suture line. On the basis of these experiments we introduced the microsurgical interfascicular nerve transplantation technique. In ITT all epineurial tissue is removed from the nerve ends and nerve anastomosis is carried out by insertion of free autologous nerve grafts. ITT has been used at the Neurosurgical Department of Odense University Hospital since the Autumn of 1977. Our initial experience has been published elsewhere (Haase & Husby 1977).

MATERIALS

A 3-year period from August 1977 to July 1979, 24 patients (pts.) with total severance of the

median n. had suture carried out using the ITT method. One patient (pt.) failed to appear for the follow up study, and one had died of an unrelated disease. Thus our material consists of 24 pts., 22 males and 2 females, who were observed for 3-5

years. Nineteen were injuries from glass, two from saws, one from a knife, one from high voltage electricity, and one was in connection with severe soft tissue contusion. Four pts. had a complete transection of the ulnar n. and one of the medial antebrachial cutaneous n. These nerve lesions were also treated with ITT. One pt. had a lesion of the radial artery, three of the ulnar artery, and two of the brachial artery. The brachial artery was reconstructed in both these cases. Fourteen pts. had complicating tendon injuries of which 10 involved the tendon of the long palmar muscle, six of the flexor carpi radialis, three of the flexor carpi ulnaris, six of the superficial finger flexors, four of the deep finger flexors and four of the flexor pollicis longus. The pt. with electrical burns had extensive loss of skin substance at the wrist which after revision was

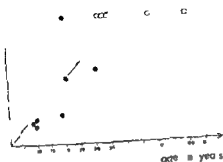


Figure 3 2 PD correlation with age
 ○ Low lesion
 ● Low lesion ideal case
 □ High or intermediate lesion

RESULTS

It developed a slight wound infection no serious complications were entered. Two pts developed light anesthesia in the region of the resected n. Palpable neuromas of which 10 visible were found in 17 pts (71 per cent). Eight neuromas were slightly tender to touch. Only one pt had severe pain and tenderness on an attempt to touch. Respiration was normal in six pts and tactile sensibility was normal in six. Protective tactile sensibility was normal in 23 pts. Of the 20 pts with low lesions, 10 achieved good restitution of the sensory function (S 3+/S 4). Only one achieved an unsatisfactory result (S 2+). 2 PD was evaluated for each finger and the results for the 2nd finger plotted as a function of the ages (Figure 3). In the age group ≤ 20 (10 pts.) the 2 PD was ≤ 10 mm for 7. In the age group > 20 years (10 pts.) there were no pts with a 2 PD ≤ 10 mm. The difference was significant ($P=0.01$) by Fisher's exact test. Of the four high and intermediate lesions, one pt attained good restitution (S 3+/S 4), one reached S3 and one S2. None achieved a 2 PD.

To test for motor recovery in the hand the abductor pollicis brevis muscle was assessed. Of the 20 low injuries 15 achieved function at the level of M 4/M 5 (75 per cent). Of the remaining five low injuries, two pts showed no signs of regaining motor function in the hand (M 2).

As regards the four high and intermediate lesions, two regained function between M 5 and M 3, and two did not show signs of regeneration (M 0/M 1).

As seen in Table 1 the sensory and motor recovery are not greatly influenced by the graft length.

The pick up test registered the number of objects collected blindly in 20 seconds. Six pts collected 0 objects, nine pts between 1 and 4 and nine pts between 5 and 10 objects.

Eleven pts were school children or students at the time of the follow up. None of them felt particularly hampered by the injury. Three pts were unemployed. Five felt impeded in their daily function but coped with their work as before the accident. One had relinquished his occupation and three changed occupation. Finally, a 50-year-old pt. had been regarded as a middle-grade disablement person because of the nerve injury.

DISCUSSION

Great inhomogeneity of clinical materials makes strict comparison difficult. Our results

Table 1 Graft length and recovery

Motor/ sensory recovery	Graft length (mm)		
	below 15	26-50	51-100
M 4-M 5	1		
S 3+-S 4	1	12	3
		9	1
M 3	1		
S 3	2	2	1
		5	4
M 2			
S 2+	2		
	1		
M 0-M 1			
S 2			

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REDUCTION AND PIN FIXATION OF SEVERELY DISPLACED SUPRACONDYLAR FRACTURES OF THE HUMERUS IN CHILDREN

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Out of 87 displaced supracondylar fractures of the humerus in children, 17 were treated by open reduction and internal fixation, in eight cases because of vascular complications (with or without neurological complications) and in nine cases after unsatisfactory closed reduction. In the eight cases with vascular impairment, evacuation of the haematoma, reduction of the fracture and division of the fascia of the forearm caused a return of the radial pulse. Median nerve paralysis, in the four cases with neurological complications as well, recovered within 7 months. Fractures fixed with one pin only redislocated and needed an additional reduction—this procedure was associated with impairment of the range of motion. In spite of the selection of the most severe cases for surgery, the end result was excellent in all cases except one and considerably better than previous results of closed reduction. Rotational deformity, however, did not decrease with age and growth.

Key words: humerus, neurovascular complication, pin fixation, supracondylar fracture

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management of severely displaced supracondylar fractures of the humerus in children still remains a challenge. More or less serious complications, such as the Volkmann's ischaemia, nerve injuries, residual rotational deformities, cubitus varus and valgus, and osteomyelitis may occur as a result of fracture and/or the treatment (Blount 1972, Tachdjian 1972, Spitzer & Paterson 1972). Various methods of treatment have been recommended in the past, such as closed reduction with external or internal fixation or a combination of both, and skin or skeletal traction (Tachdjian 1972). Most authors are still of the opinion that this fracture should almost never be dealt with by closed reduction and/or internal fixation (Blount 1955). Contrary to this opinion,

Svensson (1948), Gruber & Hudson (1964), Jones (1967), Carcasonne et al (1972), Childress (1972), Fowles & Kassab (1974), Nassar & Chater (1976), Shifrin et al (1976) and Arino et al (1977) recommend percutaneous pinning or open reduction and internal fixation.

The purpose of this investigation was to study the results of open reduction and internal fixation in a series of cases where conventional, conservative methods had failed.

PATIENTS

In 1972–1977 altogether 87 cases (56 boys and 31 girls) of dislocated supracondylar fracture of the

Table 1 Operated cases classified according to sex, fracture side, type of trauma and type of

	Boys		Girls	
	10		7	
Fall from height + run over	1		13	Extension type
Fall from height	14	17	3	T-type
Fall on level ground	2		1	Flexion type + fractured humerus, radius, ulna
	6		11	
	Right side		Left side	

humerus shaft were recorded in the Department of Orthopaedic Surgery, Malmö. Of these, 17 were treated by open reduction and internal fixation. The age of the operated cases was 9 ± 3 years—significantly higher ($0.01 > P > 0.001$) than for the unoperated cases (7 ± 3). The distribution of the operated fractures is shown in Table 1 and the circumstances which precipitated the surgical procedure in Table 2. Those cases in whom the radial pulse could not be felt with certainty in any position of the elbow joint—not even after an attempt at closed reduction—were considered to have a vascular complication.

Surgical procedure

medial intermuscular septum immediately distal to the medial epicondyle of the humerus and in those instances in which the neurovascular bundle was inspected, extending along a curved line on the anterior aspect of the forearm. In addition, a short incision was made over the lateral epicondyle for the insertion of a lateral pin. The ulnar nerve was localized, the fracture haematoma removed and the fracture reduced with a visual check being made of the reduction. The fracture was then stabilized with

pins, one from the medial and one from the lateral epicondyle, extending into the proximal humerus. In three additional cases, the lacertus fibrosus

seven of the cases the artery was torn between the proximal fragment of the bone and the lacertus fibrosus, whereas, in one case fracture haematoma alone appeared to have caused the compression. In several instances the wall showed signs of external compression. However, vascular surgery was unnecessary in all cases; arterial pulsation returned within minutes after the decompression.

External fixation in plaster was applied for 6 weeks. The pins were removed after an average of 4 weeks.

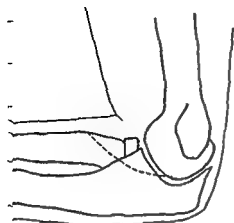
In the three cases, where the fracture was stabilized with one pin only, rotational deformity occurred. These cases were reduced again within a short time by closed reduction.

METHODS

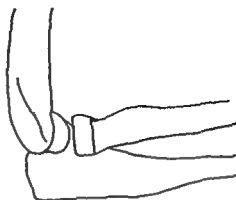
The patients were examined clinically and radiologically 1–6 years after the injury.

Table 2 Operated cases classified according to reason for surgery

Vascular complication + paresis of the median nerve	4	3 total paresis 1 partial paresis
Vascular complication	4	
Unacceptable deformity after closed reduction	9	5 extension type 3 T-type 1 flexion type + fracture of humerus, radius, ulna



Ulnar side



Radial side

1 Surgical approach

INCISION

1 --- extended incision for exploration of the neurovascular bundle and the fascia of the forearm

angulation were determined exteriorly, comparing to the contralateral elbow as normal. Logically the ossification of the epiphyses and shape of the bones were studied on standard anteroposterior and lateral projections of both sides. The degree of rotational displacement along the longitudinal axis of the humerus was determined using the radiological method described by us (1961, 1975) and Lonnroth (1962). Thus, by making a series of exposures, the true lateral projection of the plane through the posterior surface of the shaft of the humerus (the former proximal fragment) and the true lateral projection of the distal fragment (the former distal fragment) were identified. The degree of tilting between the two projections indicated the rotation. An analysis of the static movement of the radial capitulum indicated the direction of rotation (Figure 2).

The following inward rotation is defined as that causing a volar dislocation of the radial head and outward rotation as that causing a lateral dislocation. Since there may be a naturally occurring rotation between the plane through the distal end of the shaft of the humerus, the ulnar elbow was also examined in the same way. Residual rotational displacement in the ulnar elbow was defined as deviation from the normal rotation on the contralateral side in the same way.

RESULTS

There were no postoperative vascular complications. In the one case of interosseous branch paralysis—partial median nerve injury the function was restored within 3 weeks, whereas the three cases of total median nerve paralysis recovered within 4, 6 and 7 months, respectively. The range of motion in the elbow joint was gradually restored and the deviation from normal, at the time of the follow-up examination was only minor (Table 3). Pronation and supination normalized within 3 months after the injury.

A significant varus deformity of the elbow was only observed in a few cases (Table 4). The most marked residual displacement and restriction in range of motion were observed in two of the three patients whose fractures had been fixed with one pin only and had subsequently required additional reduction. Radiologically, dislocation of the distal fragment in the lateral, antero-posterior or longitudinal direction was negligible in all



a



b



c



d

Figure 2 Five-year-old girl with a dislocated supracondylar fracture of the left elbow (a and b). The partial paralysis of the median nerve (the interosseous branch) and the radial pulse could not be felt even after an attempt at closed reduction.

At operation there was a large haematoma; the brachial vessels and the interosseous branch of the median nerve were compressed between the proximal bone fragment and the lacertus fibrosus. After evacuation of the haematoma and reduction and pin fixation of the fracture (c and d) arterial pulse returned.

The median nerve paralysis recovered within 3 weeks.

Three months after injury pronation and supination were normal and flexion and extension were 10 degrees each.

At examination 1 year later extension was restricted by 5 degrees; in all other respects the elbow was clinically normal.



cases Examination of the natural rotation in the uninjured elbow showed an inward rotation in all cases (5° in eight cases, 10° in seven cases and 15° in two cases) Related to this, the residual rotational displacement in the operated (injured) elbows was minor (Table 5) In some patients, the condylar region was slightly deformed, but the joint surfaces were always congruent and smooth (Figure 2) Accelerated ossification of the epiphyses of the elbow joint (not only of the distal humerus) was also noted In those patients in whom the ossification of the epiphyseal plates had ceased, the condylar part of the humerus as well as the proximal parts of the radius and the ulna were somewhat larger than on the uninjured side There was no relationship between the rotational displacement and the follow-up time (Figure 3)

Table 3 Restriction of the range of flexion and extension in the fractured elbow at follow-up as compared with the contralateral side

	0°	5°	10°	15°	20°	25°	30°	35°	Number of observations
3 months	—	1	2	1	2	1	5	3	15
6 months	—	6	4	1	1	—	1	—	13
1-6 years	9	3	3	2	—	—	—	—	17

DISCUSSION

In spite of the fact that only the most severe cases of supracondylar fracture are included in this series, the results are better than those previously reported after closed reduction or traction. Varus deformity exceeding 10° occurred in a series reported by Lund et al (1976), in four out of 22 cases treated with traction and in eight out of 16 cases treated with closed reduction and plaster fixation, as compared with one out of 17 in the present series. Also, in comparison with a series of 545 fractures of Henriksson (1966), which included also 138 non-displaced supracondylar fractures our results are better (Table 6).

One pin only provided insufficient fixation and led to an increase in rotational displacement requiring an additional reduction and resulting in decreased range of motion. Furthermore, this study does not support the statement of Vahvanen & Aalto (1978) that rotational displacement decreases slowly with time.

It is recommended that failure to feel the radial pulse or other such signs of a compartment syndrome indicate that open reduction to relieve the pressure should always be undertaken, whereas nerve injury or an inadequate closed reduction are not such definite indications for surgery. The surgical

Table 4 Varus angulation of the fractured elbow at follow-up as compared with the contralateral side

	0°	5°	10°	15°
Number of cases	14	1	1	1

Table 5 Residual rotational displacement of the fractured elbow at follow-up as compared with the contralateral side

	Inward 10°	Neutral 5°	Outward 10°
Number of cases	3	9	4

Residual rotational displacement

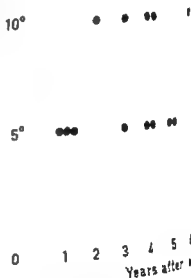


Figure 3 Residual rotational displacement of the fractured elbow at follow-up as compared with the contralateral side

Table 6 Classification at follow-up according to Henriksson's criteria (1966)

	Excellent	Good	Bad
Henriksson (1966)	396	114	1
Present study	16	1	—

ure should include the use of a tourniquet. A medial incision is recommended. Awareness of neurovascular complications. The incision should be extended to the medial aspect of the forearm. A small lateral incision is sufficient for pinning the lateral humeral epicondyle. The ulnar nerve should be localized. The haematoma removed and the fracture fixed with visual inspection and then fixed with pins — note that the cortex is thin. A suture may be attached to the head of the pin to make it easier to locate them at a later stage. If the radial pulse is not palpable, the tourniquet must be removed, the vessels explored and the fascia of the anterior compartment of the forearm divided. Plaster and pins removed 4 weeks after operation.

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RECOVERY FROM PRIMARY SHOULDER DISLOCATION AND ITS COMPLICATIONS

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Out of 226 patients with primary shoulder dislocation followed up for 1 year, 57 (25 per cent) had one or more complications. There were 25 plexus lesions, 19 axillary nerve lesions and 26 rotator cuff ruptures.

The 127 patients over 50 years of age (56 per cent) plus 53 patients under 51 years were immobilized for 1 week with a mitella. The remaining 46 patients under 51 years were immobilized for 3 weeks.

Recovery was ascertained in terms of the time needed to regain normal mobility of the shoulder, the disappearance of signs of nerve lesions and the length of the sick leave period. A total of 163 (72 per cent) of the patients achieved normal mobility in 3 months, but 42 shoulders (19 per cent) were still not fully mobile after 1 year. The mobilization was significantly retarded by advanced age, long immobilization, long "non-reduced period", rotator cuff rupture, and a severe primary dislocation. Students and office workers regained normal mobility of the shoulder in a shorter time than manual labourers ($P < 0.001$) or persons in retirement ($P < 0.001$) and manual labourers required a longer sick leave period than office workers ($P < 0.001$). There was no difference regarding recovery from axillary nerve or plexus lesions, but the patients under 51 years with nerve lesions obtained a more complete cure than the older patients ($P < 0.05$). All patients with complications (except one patient with a rotator cuff rupture) returned to work during the follow-up period.

Key words: nerve lesions, recovery of function, rotator cuff rupture, shoulder dislocation.

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More severe trauma causing primary shoulder dislocation and a longer "non-reduced period" imply a greater frequency of axillary nerve and plexus lesions and rotator cuff ruptures (Pasila et al. 1978). The prognosis of nerve lesions depends on the extent of damage to the nerve fibrils which can initially be assessed clinically. Assmus & Meinel (1976) have recommended needle stimulation and nerve conduction tests for estimation of the extent of nerve damage in shoulder injuries. They reported that partial recovery of the axillary nerve frequently occurred in 2-6 weeks and in complete

paralysis spontaneous re-innervation could be expected to ensue within 1 year, although the prognosis was poor in patients showing no recovery 8-10 weeks after injury (Assmus & Meinel 1976).

Total loss of axillary nerve function results in weak abduction, although a normal range of active abduction may be attained (London 1971). On the other hand, when there is loss of plexus function the patient may be prepared to accept an artificial limb (Yeoman & Seddon 1961). Rupture of the rotator cuff gives rise to persistent insufficiency of the shoulder (Codman 1934). The extent of the

rupture is only measurable when the rotator cuff is exposed. Tears of more than 2 cm cause considerable disability (Bakalim & Pasila 1975). Residual stiffness in the shoulder is seen in older patients after dislocation (London 1971).

A follow-up for 1 year, from the time of injury, of patients with primary shoulder dislocation was arranged. Functional restoration of the shoulder and recovery after axillary nerve and plexus lesions and rotator cuff ruptures were recorded.

PATIENTS

This study comprises 238 primary shoulder dislocations treated during the period 191971 to 31121976 in the Department of Orthopaedics and Traumatology, University Central Hospital, Helsinki, Finland.

One investigator attended to the follow up of 226 patients over a period of 1 year. Initially, the patients visited the Physical Medicine Department weekly and later, at intervals implied by the treatment. There were 126 men and 100 women, 127 (56 per cent) were older than 50 years. Ninety-seven patients were manual labourers, 45 office workers, 71 in retirement, and 13 were students.

The mechanism of trauma could be reconstructed in 142 primary dislocations. Patients with a "non-reduced period" in excess of 36 hours were excluded from the study.

METHODS

Axillary nerve and plexus lesions were diagnosed by the location of paretic muscles and defects of skin sensitivity. No quantitative measurements of the severity of the nerve lesions were made.

In the 127 patients (56 per cent) over 50 years of age connections between the articular cavity and the subacromial bursa were common (as a result of slowly progressing degeneration). When the trauma resulting in dislocation rendered such shoulders painful the diagnosis was postponed a few weeks so that the initial pain could subside and it was only made in rotator cuff perforations with a persistent clinical picture of rotator cuff rupture (Pasila et al 1978). Thus 57 patients (25 per cent) had 70 complications in all: 25 plexus lesions, 19 axillary nerve lesions and 26 rotator cuff ruptures. One single lesion was found in 45

shoulders, and 12 shoulders presented no complication.

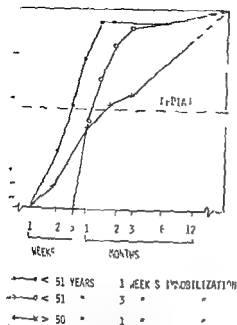
All 127 shoulders of patients over 50 years of age and 53 shoulders of younger patients were immobilized for 1 week with a mitella. The younger shoulders of patients under 51 years were immobilized for 3 weeks by tying the arm to the side of the thorax. At the end of the immobilization period the patient was encouraged to mobilize his shoulder. If this proved difficult, a physiotherapist (the same for all the patients) supervised exercises. The mobility of the shoulder was regarded as normal if in interval rest the shoulder the patient could touch the back area, and if the limitation of outward rotation and active flexion were both not more than 10°.

Recovery from axillary nerve and plexus lesions was assessed by the disappearance of symptoms of nerve lesion and the recovery of sensation and muscle force. A nerve lesion was regarded as cured when any slight residual muscle force and skin sensation did not inconvenience the patient.

RESULTS

Mobilization was slow and incomplete. In 127 patients over 50 years (Figure 1), in the older group, 38 patients failed to attain normal mobility of the shoulder within 1 year. The corresponding number of stiff shoulders in the younger group was two out of 53 patients immobilized for 1 week and 11 out of 46 patients immobilized for 3 weeks. The increase in the immobilization period from 1 to 3 weeks in patients over 50 years of age caused the median time for recovery of normal mobility of the shoulder to be lengthened by 2 weeks (from 3 to 5 weeks). This difference is statistically highly significant ($P < 0.001$). The time needed for normal mobility to be regained was 4 weeks in 99 patients under 50 years, and 7 weeks in the 127 older patients, a difference which is also statistically significant ($P < 0.001$).

The median time needed for recovery of normal mobility of the shoulder to be regained was approximately 1 year in the 26 shoulders with rotator cuff ruptures, 51 days in the 19 shoulders with nerve lesions and 27 days



1 Time required to regain normal mobility shoulder in three treatment groups. The satisfactory recovery was made by young with a short immobilization period

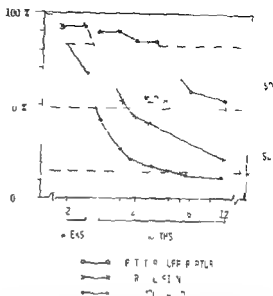


Figure 2 Time required to regain normal mobility, in shoulders free of complications and in those with rotator cuff ruptures and nerve lesions. Mobilization of shoulders with rotator cuff ruptures took the longest time ($P < 0.001$)

19 uncomplicated shoulders (Figure 2) difference between the 1-year and 51 day is highly significant ($P < 0.001$), but is no statistically significant difference in the 51- and 27-day groups. The rate of mobilization was equal, with a period of 30 days, in the following three groups: (1) 87 dislocations with a "non-reduced period" of less than 1 hour, (2) 81 with 1-3 hours and (3) 44 with a 3-12 hours "reduced period" (Figure 3). With a "reduced period" longer than 12 hours (in 15 dislocations) the median period for recovery of normal mobility was 45 months. The difference between 30 days and 45 months is statistically highly significant ($P < 0.001$).

The 15 patients who had fallen from a height represented the most violent mechanism of dislocation in this study (Figure 4). The median time needed for mobilization in this group was 60 days, compared with 30 days in the case of 92

shoulders dislocated by falling (not from a height) and with 24 days in 35 shoulders dislocated by torsion. The difference between 60 and 30 days is statistically highly significant ($P < 0.001$) and that between 30 and 24 days is significant ($P < 0.01$).

The median duration of sick leave was 16 days for 45 office workers and 30 days for 97 manual labourers. The difference is statistically highly significant ($P < 0.001$) (Figure 5). Nine office workers (20 per cent) and 3 manual labourers (3 per cent) required no sick leave at all. All 45 office workers returned to work within 3 months, and 95 of the 97 manual labourers returned to work within 9 months. The two permanently disabled manual labourers were over 60 years of age, one had four redislocations and the other had a rotator cuff rupture.

Nine out of the 25 plexus lesions, and six out of the 19 axillary nerve lesions failed to recover completely in 1 year. There was no statistically significant difference in rate of

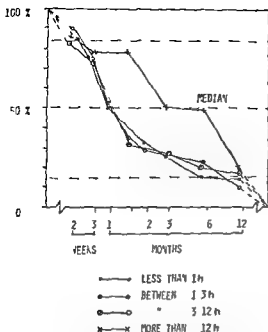


Figure 3 Effect of length of the 'non reduced period' on recovery of normal mobility of the shoulder. Patients with a 'non reduced period' of longer than 12 hours made the slowest recovery.

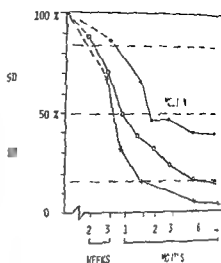


Figure 4 Effect of the mechanism of trauma on the time required to regain normal mobility of the shoulder. The greater the estimated tearing dislocating trauma the slower was the mobilization.

Table 1 Time required to regain normal mobility of the shoulder in the various social groups

Social group	Time required to regain normal mobility of the shoulder		Total
	<6 weeks	>6 weeks	
Manual labourer	57	40	97
Office worker	36	9	45
Student	13	0	13
Pensioner	34	37	71
Total	140	86	226

recovery between the plexus and axillary nerve lesions.

All eight nerve lesions in patients under 51 years, and 21 of the 36 nerve lesions in older patients, recovered within 1 year (Figure 6).

The group of office workers and students achieved a normal range of movement in the shoulder more quickly ($P < 0.001$) than the manual labourers (Table 1). The mobilization of the shoulders was slower ($P < 0.01$) in pensioners than in the rest of the patients.

DISCUSSION

The rate of mobilization slowed down at the end of the follow up period of 1 year; only four patients attained a normal mobility of the shoulder after a further 6 months. We concluded that the stiffness persists in the shoulders after 1 year was permanent. Twenty-three of these 42 stiff shoulders were complicated by rotator cuff rupture or lesion, or both. Of the patients who

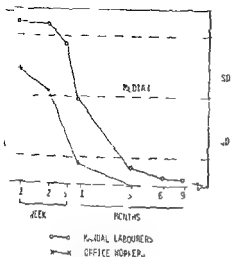


Figure 5 Length of sick leave period of manual and office workers. Manual labourers work for a considerably longer time than office workers.

ers, 21 were manual labourers, 18 were office workers and only three were office workers.

Delayed mobilization often resulted in permanent stiffness. On the other hand, earlier mobilization, 25 of the 108 patients who attained full mobility in 1 month had no recurrences during the follow-up period. 130 shoulders with redislocations were reduced in 2 months.

Initially, only two patients had such severe plexus lesions that the affected arm was totally paralysed. Usually the lesions were located in the axilla, small and distally located, inducing the surgeon at first sight to evaluate the lesions as "slight" (20/30), compared with the severe nerve lesions (8/19) in which the arm was flaccid, the deltoid muscle suggested a "complete" lesion. Because the plexus and axillary nerve lesions both recovered equally, this primary impression did not turn out to be of any prognostic value.

The nerve lesions were either initially severe or they made a good recovery as all the following patients with nerve lesions were able to return to their work during the follow-up period.

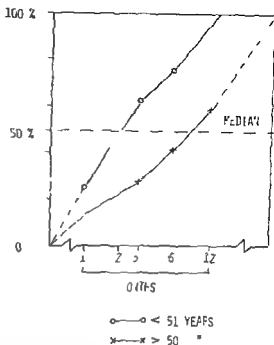


Figure 6 Recovery of nerve lesions in two age groups. The rate of recovery was almost significantly slower in the patients over 50 years of age ($P < 0.05$).

period. One carpenter with total loss of axillary function and inadequate return of nerve function had the longest sick leave 9 months. Recovery was delayed in five patients with combined plexus and axillary nerve lesions and in eight patients with a torsional mechanism of dislocation. Seven of the nerve lesions were slight enough to recover within 1 month, but it is conceivable that all transient nerve lesions may not have been diagnosed. In four of the seven slight nerve lesions the "non-reduced period" was 1 hour, and it never exceeded 3 hours. Nerve and tendinous complications seem to occur only in primary shoulder dislocation, as no complications were observed in the 30 shoulders with redislocation. Mobilization in these cases was also achieved without difficulty.

After 1 year 14 rotator cuff ruptures still showed a limitation in flexion up to 40 degrees. However, no patient had any

spontaneous pain or pain on movement of such severity as to indicate surgical treatment for rotator cuff rupture (Bakalim & Pasila 1975)

The length of the sick leave period could not be determined in the case of the 16 pensioners with rotator cuff ruptures but six out of the seven manual labourers and all three office workers with rotator cuff ruptures returned to work during the follow-up period

Mobilization was impeded by the severity of dislocation and the length of the 'non reduced period'. These together with degeneration of the shoulder joint due to advanced age and/or manual labour increased the rate of complications and reduced the tendency for redislocation

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ROPATHY IN THORACIC SCOLIOSIS

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The erector spinae muscles of 20 normal humans were evaluated at C₇, T₁₁, T₁₂, and L₄ vertebral body levels bilaterally. At each level, the mean potential duration of the motor unit action potential was calculated. This control group was compared with a group of patients with C₇ and L₄ radiculopathy and with a group of patients with thoracic scoliosis. The mean potential durations of the radiculopathy group at the C₇ and L₄ levels were prolonged as were those values at the convex thoracic levels in the scoliotic group. Muscle biopsy of the erector spinae in the scoliotic group revealed grouped atrophy and changes consistent with a neuropathic process. A radiculopathic process was associated with idiopathic thoracic scoliosis and involved the convex side. It was maximal near the apex of the curve.

Keywords: electromyography, muscles, pathology, radiculitis, scoliosis, pathophysiology

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4, the mean potential duration was
ed for the biceps brachii muscles
al et al 1954). Soon afterwards, mean
al durations were calculated for 16
muscles (Buchthal & Rosenfalck 1955).
of the muscles, except the brachialis,
ta were recorded using concentric or
electrodes. However, the mean
al durations of the biceps brachii
recorded by either concentric or
r electrodes were virtually identical
hal et al 1954). Since then, the mean
al duration has been used as a
ative electromyographic parameter. In
n, the medial portion of the erector
muscles lends itself to more accurate
myographic studies than the lateral
i (Jonsson 1969). The purpose of this
s to use the more recent technological
ss to calculate the mean potential

duration of the medial portion of normal
erector spinae muscles using monopolar
electrodes and to compare this with the mean
potential duration in patients with
radiculopathy and with scoliosis.

PATIENTS AND METHODS

Twenty unpaid volunteers were studied in the control group. The age range was between 20 and 42. The mean age was 35 and the median age was 37. Ten of the volunteers were males and 10 were females. None had a past history of diabetes, heart disease, kidney disease or any neurologic disorder.

Fourteen patients comprised the radiculopathy group. Seven had unilateral neck pain and signs and symptoms consistent with C₇ radiculopathy, and seven had a low back pain and signs and symptoms consistent with unilateral L₄ radiculopathy. All of these patients had marked

spontaneous pain or pain on movement of such severity as to indicate surgical treatment for rotator cuff rupture (Bakalim & Pasila 1975)

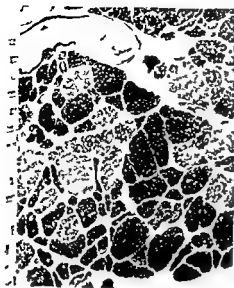
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Mobilization was impeded by the severity of dislocation and the length of the "non-reduced period" These together with degeneration of the shoulder joint, due to advanced age and/or manual labour, increased the rate of complications and reduced the tendency for redislocation

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1 Muscle biopsy—Erector spinae on the side at the T₇ level, myofibrillary ATPase pH 9.4. Dark Type II and light Type I are seen. Type II fibers are small and Note also the group atrophy of muscle.

of Type II fibers. Muscle spindle thickening was noted. In addition, intraneural nerve showed evidence of denervation and fiber type grouping was observed (Figure 1).

DISCUSSION

Our results indicate that determination of the potential duration is both accurate and reliable. The advent of trigger and signal modules make it easier to capture unit action potentials on an oscilloscope screen store or record them and examine them. At the same time, electromyographic examination of the thoracic muscles is a particularly useful procedure with spinal nerve root neuropathy. Electromyographic examination may in fact be confined to the erector spinae muscles particularly during the first 2 years after injury and is extremely important at the radicular levels with no appendicular

representation (Goodgold & Eberstein 1977). Peripheral nerve palsy has been shown to produce polyphasic potentials of long duration (Pinelli et al 1953). In patients with atrophies due to neuropathies of the anterior horn cells prolonged mean potential durations have also been noted (Buchthal & Pinelli 1953). The mean potential durations were, in fact, prolonged in those patients with radiculopathy. The prolonged mean potential durations of the convex thoracic levels in the idiopathic scoliosis patients indicate that radiculopathic processes are present in those patients as well. The results of the muscle biopsies are also consistent with the presence of a radiculopathic process.

The association of idiopathic scoliosis and radiculopathy has been controversial. Henssge (1968) and Peretti & Velluti (1969) found increased insertional activity or "denervation" potentials. Weiss et al (1957) and Alexander & Season (1978) did not find increased insertional activity or fibrillation potentials. Our study agrees with these last two studies with regard to insertional activity. However, none of these studies used percutaneous electrodes exclusively to quantitatively examine the motor unit action potentials that were produced by the medial portion of the erector spinae during spinal extension. In addition, our study presents a correlation between muscle biopsy and electromyographic results absent in the other studies.

This study does not by itself solve the question of whether or not the radiculopathic process precedes or is subsequent to the idiopathic scoliosis. It has been stated that the evolution of idiopathic scoliosis is closely associated with abnormal skeletal maturation indexes (Duval Beaupere 1970). The presence of thoracic radiculopathy in these patients would at least in part explain the abnormal growth pattern.

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VERTEBRA PLANA DUE TO A MALIGNANT LYMPHOMA

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A patient with total collapse of the vertebral bodies ("vertebra plana") is described. The symptoms and objective findings were caused by a malignant lymphoma, and the diagnosis was established from a drill biopsy. It is recommended that a biopsy be performed in patients with "vertebra plana".

Key words: drill biopsy, eosinophilic granuloma, histiocytosis X, malignant lymphoma, vertebra plana

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Vertebra plana was originally described as an osteonecrosis of bone involving the spinal body. This description has been modified by the addition of a number of disorders: eosinophilic granuloma, trauma, osteoporosis, inflammation, and malignant disease. The present paper describes a case of vertebra plana, initially misdiagnosed as histiocytosis X or eosinophilic granuloma, and which was caused by a malignant lymphoma.

REPORT

A 10-year-old boy was admitted to the hospital in 1977 with severe pain in the back not caused by trauma. X-rays of the spine showed a total collapse of the 4th and 8th thoracic vertebral bodies, diffuse osteoporosis and incipient fracture of the lumbar vertebrae (Figure 1). X-rays of the chest 1 month previously had been normal and there were no radiological changes in the ribs and long bones. Clinical and neurological examination was normal. Blood analyses including white blood counts and liver enzymes were normal and Mantoux was negative. Sedimentation rate was 28 mm per 1 hour. ^{99m}Tc -isotope bone scan showed abnormal activity in the thoracic vertebrae. The patient was regarded as having vertebra plana possibly due to an eosinophilic granuloma and was observed in bed. X-rays 3 months later showed no further changes, but after 5

weeks a progression with collapse of the 5th and 7th thoracic vertebrae was observed. The sedimentation rate had increased to 60 mm per 1 hour. Histologic examination of the bone marrow showed malignant tumour cells of unknown origin. The patient was subsequently transferred to another hospital (Rigshospitalet, Copenhagen) and a drill biopsy of the third lumbar vertebra was performed. Histologic examination showed anaplastic cells from a malignant lymphoma, probably of reticulum cell type (signed A. Halveg).

Chemotherapy with Prednisone, Cyclophosphamide, Oncovine was then started and the patient was mobilized in a brace. During the following months the radiological changes subsided, but after 1 year the condition worsened and the patient died in November 1978. Autopsy was not performed.

DISCUSSION

In the first description of vertebra plana Calve (Calve 1925) laid down the following criteria: 1) total collapse of only one vertebra, 2) no involvement of the intervertebral disc, 3) the intervertebral space at least one third wider than normal, 4) increased density of the involved vertebra. Calve stated that the changes might be due to some sort of aseptic bone necrosis.



(A)

(B)

Figure 1A, B X-rays of the thoracic and lumbar spine

In 1954 Compere et al. reported four cases of vertebra plana with the same radiological changes. Histologic examination of biopsies from all four patients showed that the collapse was due to an eosinophilic granuloma. This was also found by Kieffer et al. (1969), who furthermore stated that several patients with eosinophilic granuloma

had affection of more than one vertebra. One patient had changes in the feet as well. Identical findings were found by Poulsen & Thomsen (1976). Eosinophilic granuloma is, however, not always the cause of vertebra plana (Ennis et al. 1970). Poulsen et al. (1975) found ten cases of Ewing sarcoma among five patients

4 plana Ewing sarcoma is only rarely
1 to the spinal column, and they
ed that an open biopsy should always
rmed

1 patient initially presented with
2 of two thoracic vertebrae with no in-
ent of the intervertebral disc and no
ue swelling was seen. It was not until
y from the iliac crest was taken that
n of a malignant disease arose and
1 diagnosis was only established after
needle biopsy was taken from one of
thoracic vertebrae which had also col-

oms very unlikely that the changes in
thoracic vertebrae were caused by a
other than that in the thoracic verte-
ence the radiological pictures were
d as the disease progressed
more the temporary remission after
therapy was started was seen in both the
and the lumbar spine
must be emphasized that all patients
vertebra plana should be regarded as

having a malignant tumour until proven
otherwise. A way to prove or exclude this is
by taking a biopsy from the affected vertebra.

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LAGEN CHANGES IN CONGENITAL AND PATHIC SCOLIOSIS

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Collagen abnormalities in adolescent idiopathic scoliosis have been recorded. In this condition the platelet aggregating power of collagen is decreased and the amount of collagen in suspensions prepared from fascia is increased. We found the same abnormalities in two out of four patients with congenital scoliosis, operated on according to Harrington. In idiopathic as well as in congenital scoliosis the decrease in the platelet aggregating power was more conspicuous in the younger patients.

Key words: collagen, congenital and idiopathic scoliosis

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n, the most important supportive
of connective tissue, has been shown
re defective properties in adolescent
hic scoliosis (AIS) (Francis et al 1977,
l et al 1978, Uden et al 1979). In AIS
ubility of collagen in weak acetic acid
reased and the platelet aggregating
is diminished (Uden et al 1979).
changes can be explained by an altered
inking, or by a decreased content of
II collagen, which is less soluble and
increased platelet aggregating activity
sen et al 1975). This paper compares
n in congenital scoliosis with that in

genital scoliosis had a unilateral bar on the
concave side at the apex of the curvature. Two
patients also had several hemivertebrae. The
patients were operated upon according to
Harrington and biopsy specimens were obtained
from fascia of the longitudinal dorsal muscles.

METHODS

Collagen suspensions were prepared as described
in detail elsewhere (Uden & Nilsson 1978). The
pieces of fascia were scraped clean and freeze-
dried in a vacuum. 8.35 mM acetic acid was added
in an amount corresponding to 50 times the
weight of the specimen after which the mixture
was homogenized for 60-90 seconds with a pestle
and a glass mortar. An equal volume of distilled
water was then added and homogenization was
repeated. During the homogenization the mortar
was kept in ice-cold water. The suspension was
stored at -60°C. Before being used it was
rehomogenized and centrifuged at 1200 g for 30

TRIAL

lateral consisted of four patients (15 ± 3
with congenital scoliosis (Table 1) and
patients (15 ± 2 years) with AIS. The
curvature ranged from 47°-80° and
10°, respectively. All the patients with con-

used to determine the platelet aggregating ability
of the collagen.

The platelet aggregating ability was assessed
photometrically with a Payton Dual Channel

vestigation was supported by grants from the
Research Council (B79 19X-00087-15B
3-17X-04780-03).

Table 1 Four cases of congenital scoliosis CC per cent = minimal concentration of collagen in plasma (PRP) that induces platelet aggregation, relative to that of a standard collagen

Sex	Age years	Defect of the vertebrae	Collagen in suspension, mg/l	CC per cent
M	17	Unilateral bar + hemivertebrae	140	79
M	18	Unilateral bar	25	60
F	14	Unilateral bar	85	20
F	11	Unilateral bar + hemivertebrae	120	100

Aggregation Module, also described by Udén & Nilsson (1978). It implies constant magnetic stirring and constant recording of the transmission. The lowest concentration of collagen in platelet-rich plasma (PRP) that induced platelet aggregation was called the critical concentration (CC). PRP was obtained from healthy volunteers. Since the responsiveness of PRP even from healthy persons varies, the CC was expressed in relation to that of standard collagen (CC per cent).

In the statistical treatment of the data, Student's *t*-test for differences between means, and Pearson's linear correlation test were used.

RESULTS

The mean collagen concentrations in the suspensions from the two groups were equal, as was the mean CC per cent, which reflects the platelet aggregating power (Table 2).

Compared with the findings in non-scoliotic controls (Udén et al 1979) the concentration of collagen in the suspensions was significantly increased in congenital scoliosis ($P < 0.05$) as well as in idiopathic scoliosis ($P < 0.05$). In neither of the scoliotic groups did the platelet aggregating power of the collagen (CC per cent) differ significantly from the control value but a difference was found when the two groups were pooled ($P < 0.01$). This implies a decreased platelet aggregating power of the collagen of the scoliosis patients regardless of type.

The CC per cent varied inversely with the patient's age, ($r_{12} = -0.69$), which means that

the collagen of the younger patient more reduced platelet aggregating power.

There was also a slight but not significant correlation between age and content of the solution ($r_{12} = -0.46$).

The material, five boys and five girls, showed no significant sex difference in either collagen content of the suspension (86 ± 43 mg/l and 95 ± 39 mg/l, respectively) or the mean CC per cent values (54 ± 30 per cent and 54 ± 40 per cent, respectively). The values in the girls were not significantly higher than those in the boys.

DISCUSSION

described by Ponseti & Smith (1966) induced scoliosis in rats with β -casein p-nitrophenyl ester. Scoliosis has also been reported in a highly inbred strain of mice with a collagen defect, characterized by increased solubility in 4 M urea (Ponseti et al 1977). When it was also found that properties of collagen in adolescent scoliosis (AIS) differed from the control, it was suspected that defective collagen was the cause of AIS. If congenital scoliosis was solely by anomalies of the vertebral bodies, we would not expect the same collagen changes as in AIS. However, we found the same changes as in AIS, i.e. a decrease in

→ Results of the analysis of collagen from patients with congenital and idiopathic scoliosis (AIS). The for AIS II and controls are from an earlier paper (Udén et al 1979). CC per cent = minimal content of collagen in platelet rich plasma (PRP) that induces platelet aggregation, relative to that of a standard collagen.

	Number	Male	Female	Age years av \pm s.d.	Collagen in suspension mg/l, av \pm s.d.	CC per cent of standard av \pm s.d.	Range
total scoliosis	4	2	2	15 \pm 3	90 \pm 50	540 \pm 470	60-1080
	8	3	5	15 \pm 2	90 \pm 30	420 \pm 310	140-1130
	15	1	14	18 \pm 4	130 \pm 20	770 \pm 550	150-2050
Is	10	7	3	19 \pm 6	50 \pm 20	180 \pm 110	60-400

ility in weak acetic acid and a decreased aggregating power.

genital scoliosis is a rare condition - in samples could be obtained from only cases. Consequently, the value of the ical methods is limited. However, in if the cases of congenital scoliosis the cent values were well above the upper of the normal range and more on the f that in AIS (Tables 1 and 2). There is no ice that the collagen defect in congenital is the same as in idiopathic scoliosis. ver, two of the cases showed signs of a r abnormality. This was perhaps because r fascia specimens were obtained from cases. Only relatively few cases of con- l scoliosis, as well as idiopathic scoliosis, orate to this degree during adolescence. ly such severe deformities require some ing disturbance of the collagen. Any test s hypothesis would require inclusion of with mild deformities.

sex ratio was not the same in the two. However, the variation of the pro- s of collagen with sex was not ically significant and cannot explain the nce found between the patients with sis and the controls.

e correlation between age and platelet ating properties of the collagen has observed earlier by Udén et al (1979) in that study it was not statistically icant. The finding that this abnormality re pronounced in younger patients is in ment with Francis et al (1977).

It is known that the amount of reducible cross-links of collagen varies with the growth rate (Bailey et al 1974). Perhaps this is one cause of the frequently observed progression of both congenital and idiopathic scoliosis during the prepubertal growth spurt (Farkas 1954, Shands & Bundens 1956, Duval-Beaupère 1971, Clarisse 1974).

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QUANTITATIVE ANALYSIS OF THE GROWTH OF THE HIP JOINT

A Radiological Study

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Growth of the hip joint is described on the basis of annual radiographs

that of the proximal metaphysis and accordingly, in the case of normal ossification, the radio-anatomical condition of these two parts is characteristic of the age of the individual. The osseous acetabulum also grows at a faster rate in breadth than in depth. In the period studied up until the 15th year the width of the "articular space" gradually decreases. The ossification rate in the age group examined manifests — with slower and faster periods — a gradually declining tendency. The changes revealed by the radiographs have been interpreted from the viewpoint of bone development and an analysis is also given of the spatial conditions of ossification.

Key words: acetabulum, articular space, femoral head, growth of hip, ossification rate, radio-anatomical condition

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Aspects of the growth and development of the hip joint have become known as a result of research in the last few decades (Klein 1962, Gardner & Gray 1970, Lanz & Wachsmuth 1938, yet 1953, Lanz & Wachsmuth 1938, yet 1939). Investigations into the aetiology of congenital dislocation of the hip as well as the problems of its treatment have drawn attention to the hip joint and to its development. As a result of these investigations, among the quantitative features of development and growth, the relations between the proximal femoral end and the acetabular angle [collodiaphyseal angle, CE angle's angle, antetorsion, etc.] have also been traced and described in detail (Klein et al. 1962, Lanz & Wachsmuth 1938, Wiberg 1949). Substantially less is known about the

ossification processes occurring in the later stages of growth. In fact, knowledge of this period is almost exclusively confined to the angular relations mentioned above; other quantitative characteristics of growth are missing. Klein et al. dealt with the morphological changes concomitant with the growth of the proximal end of the femur.

Knowledge of the quantitative features of growth of the hip joint in childhood and puberty may very likely explain the numerous coxalgias manifesting themselves at this age, as well as the pathomechanism of the resultant deformations. Hence, for example, determination by means of quantitative features of the scale of articular deformation occurring in Perthes' disease, which has been found to be satisfactory in practice and better

than any other method applied so far, enables the establishment of a very exact diagnosis of this deformation (Glauber & Kéry 1975 Heyman & Herndon 1950 Kéry 1970 Meyer 1964)

Our investigations aimed at recognizing those quantitative data which characterize normal growth and ossification of the hip joint in childhood and puberty

PATIENTS AND METHODS

For the investigation we used the intact hip joint of young male patients suffering from Perthes' disease in whom according to the most exact radiological and clinical analyses the osteochondrotic changes were undoubtedly only unilateral. On these intact hip joints and on the so-called intact hip joints of patients suffering from Perthes' disease none of the radiological changes described earlier by other authors (Chivabongs 1972 Kráncz et al 1976) could be detected nor were any changes observed hinting at dysplasia or other coxalgias. In order to trace the development we chose 50 boys in whom hip joint radiographs had been taken at least once a year for 4 years with intervals of 10–14 months. The age of the boys examined varied between 4 and 16 years; in our analysis we only used data referring to the age groups between 5 and 15 years.

Under standard conditions the measurements were performed by means of a p comparative radiographs of the hip joint. Magnification factor 1.13. For the analyses of the cases Lauenstein type radiographs were examined as well.

Seventeen parameters were measured on each hip joint: the breadth and depth of the osseous acetabulum, the radius of the acetabulum, the height and breadth of the ossification centre of the femoral head, the radius of the surface of the osseous epiphysis, the breadth of the proximal metaphysis of the femur near the growth cartilage, the thickness of the metaphyseal growth cartilage, the length of the femoral neck laterally and medially as well as the smallest diameter of the femoral neck, the breadth and height of the ossification centre of the major trochanter and in addition the width of the articular space at two places. The measured values were expressed in millimeters. Apart from the above-mentioned measurements the size of both the CD angle and CE (Weiberg's) angle were also measured.

We are in our present publication concerned only with the changes occurring during growth of

the structures (acetabulum, femoral articular space) involved in the femoral hip joint. The method applied enabled from determining the general growth, separately the growth of each hip joint.

Standard statistical formulae were used: values (mean) and standard deviation of values (s.d.) were calculated. The results referring to different age groups are based on 12–20 patients. No corrections in the magnification were made on the previously described Student's *t* test was used for significance.

RESULTS

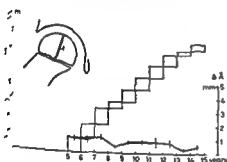
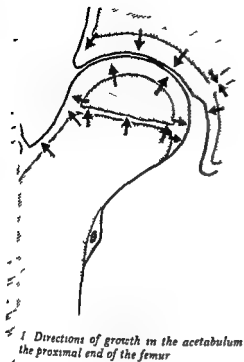
In the evaluation of the results, apart from the anatomic conditions of the acetabulum and the proximal end of the femur, the growth and ossification as well as the directions represented the starting point (Figure 1).

The ossification centre of the femoral head appears in the cartilaginous epiphysis. Its growth may be characterized by its breadth and form of the ossification centre.

The height of the osseous epiphysis was determined by the distance between the subchondral bony plate and the epiphyseal growth plate. Measurement was performed at right angles to the plane of the growth cartilage at the highest point of the ossification centre (Figure 2).

The longitudinal growth of the femoral head centre was not uniform in any of the cases, but faster and slower periods alternated. As regards the height of the centre of the femoral head, the mean growth rate in the period between 5 and 15 years was 0.8 ± 0.1 mm/year. Between 5 and 11 years the mean growth rate proved to be uniform with a transitory slowing occurring only between 8 and 9 years. After the 13th year, growth then proceeded with a gradually decreasing tendency (Figure 3).

The breadth of the ossification centre of the femoral head (B) was measured as the distance between the most medial and lateral extreme points of the ossification



$P < 0.001$ 7-8, 9-10, 10-11,
 $P < 0.01$ 5-6, 6-7, 8-9, 11-12, 13-14,
 14-15,
 $P < 0.05$ 12-13 years

(Figure 3) The breadth of the osseous femoral head showed a uniform growth in almost all cases (Figure 3) The mean growth was found to be 2.2 ± 0.2 mm/year. The growth became somewhat slower after the 10th



Figure 3 Growth in breadth (B) of the osseous femoral head as a function of age. Each curve shows in each boy growth in breadth of the osseous epiphysis. (For the sake of clarity the data of only 25 boys are included.)

year and significantly slower after the 13th year (Figure 4).

The proximal metaphysis, an important factor in the growth of the femoral head, forms also its stem. In a cap-like manner the epiphysis covers the proximal metaphysis. Its breadth (M) was measured in the region beneath the growth cartilage, from the laterodorsal angle to the most medial point of the medial "lip" of metaphysis (Figure 5). The breadth of the proximal part of metaphysis increased fairly uniformly in all individuals examined. The average growth in breadth from the period between the 5th and 6th years gradually decreased from a maximum of 2.4 ± 0.4 mm/year, and between the 13th and 14th year growth did not exceed 1.1 ± 0.6 mm (Figure 5). Taken over the whole period examined the average growth was 1.9 ± 0.1 mm/year.

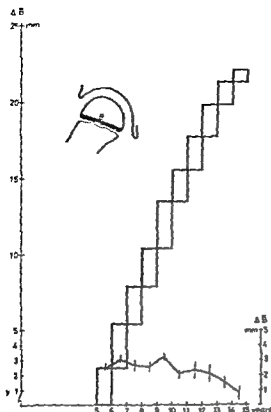


Figure 4 Growth in breadth (B) of the osseous femoral head. The columns show the average growth of the osseous epiphysis, calculated from the size (b) at the age of 5 years. The curve shows the average growth rate/year (Mean \pm s.d.)

P value $P < 0.001$ 5-6, 6-7, 7-8, 8-9, 9-10,

$P < 0.01$ 11-12, 11-12,

$P < 0.05$ 12-13, 13-14, 14-15 years

The growth of the osseous acetabulum can be characterized by the change in its breadth and depth. The breadth of the acetabulum was taken as the distance between the top edge of the osseous acetabulum and the inferior point of the medial "U" formation (line b Figure 6), and its depth at the point of greatest depth at right angles to the line of the breadth measurement (line a Figure 6). Growth in breadth of the osseous acetabulum was throughout the period studied fairly considerable with an average increase of 2.5 ± 0.1 mm/year. Growth in depth of the acetabulum was much slower, being on average 1.0 ± 0.1 mm/year. Growth of both acetabular dimensions slowed down between the 8th and

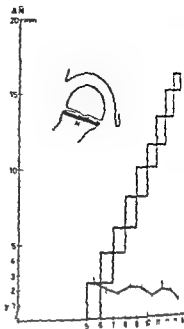


Figure 5 Growth in breadth (B) of the femoral metaphysis (M) in boys. The columns show the average growth of the femoral metaphysis, calculated from the breadth (b) at the age of 5 years. The curve shows the average growth rate/year (Mean \pm s.d.)

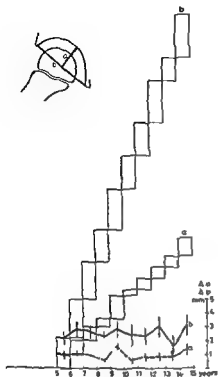
P value $P < 0.001$ 5-6, 6-7, 7-8, 8-9,

$P < 0.01$ 10-11,

$P < 0.05$ 11-12, 12-13, 13-14

9th year, then accelerated again between the 9th and 10th year. The breadth was slower growth between the 11th and 12th year and thereafter increased again between the 14th and 15th year. Growth of the acetabular depth, compared to the earlier also increased slightly. The curve shows the average values of the measurements.

The distance between the osseous acetabular floor and the osseous femoral head, so-called articular space was measured in the proximal part of the joint, in the "weight-bearing" area (C) and medially in the acetabular fossa (D) (Figure 7). At the points the width of the articular space decreased gradually with advancing age. The width of the "weight-bearing" area increased rather slowly between the ages of 5 and 10 years, but thereafter rapidly increased.



6 Growth in breadth (b) and depth (a) of the acetabulum in boys. The columns show the growth calculated from the size (b) at the years. The curves show the average annual rate (\pm s.d.) in breadth (b) and depth (a) of the acetabulum.

of "a" $P < 0.001$ 7-8, 8-9, 9-10,
 $P < 0.01$ 5-6, 6-7, 10-11, 11-12,
 $P < 0.05$ 12-13, 13-14, 14-15
years

of "b" $P < 0.001$ 6-7, 7-8, 8-9, 9-10,
 $P < 0.01$ 11-12, 12-13,
 $P < 0.05$ 10-11, 13-14, 14-15
years

At the 15th year approached the size characteristic of the adult hip joint. Parallel narrowing of the "weight-bearing" narrower weight-bearing zone of the femur developed, the medial part of the cavity being wider near the acetabular (Figure 7).

DISCUSSION

In the present investigation a serial observation of the growth of the hip in the same in-

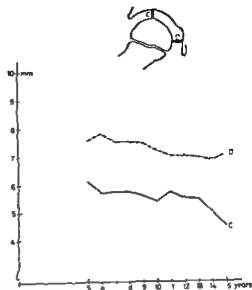


Figure 7 Growth of the "articular space" in the hip joint of boys. C - size of the articular space in the "weight bearing zone", D - size of the articular space in the acetabular fossa.

dividuals was carried out. The growth of the hip joint was studied in the period between 5 and 15 years of age, providing data hitherto unavailable in the medical literature.

Growth of the joints occurs together with growth of the cartilaginous epiphysis of the articulating bone ends. Growth of the ossification centre (osseous epiphysis) depends on the growth of the cartilaginous epiphysis and this is followed by the formation of bony tissue (ossification).

Growth of the ossification centre of the femoral head occurs as a result of ossification on an almost hemispherical surface. On radiographs growth of the osseous epiphysis that can be measured linearly in plane projection in fact shows the above-described characteristic features. In order to demonstrate the true quantitative conditions we chose a period in which breadth of the ossification centre of the femoral head increased from 28 mm to 32 mm and its height from 14 mm to 16 mm. In this period the ossification centre of the femoral head manifested a linear growth of merely 14.28 per cent but the ossification surface would at the same time

Table 1 Average measurements of the bony constituents of the hip

Age (years)	Osseous femoral head		Mean values in millimetres (mean \pm s.d.)	
	height	breadth	Proximal femoral metaphysis breadth	Osseous depth
5	12.4 \pm 1.0	25.5 \pm 2.3		
6	13.6 \pm 1.1	28.0 \pm 2.7	29.4 \pm 1.7	13.9 \pm 0.9
7	14.4 \pm 1.6	31.3 \pm 2.7	31.8 \pm 1.7	15.2 \pm 1.1
8	15.4 \pm 1.4	34.1 \pm 3.0	33.6 \pm 2.0	16.3 \pm 1.7
9	15.7 \pm 1.7	36.9 \pm 2.4	35.3 \pm 1.7	17.6 \pm 1.7
10	16.2 \pm 2.0	40.0 \pm 2.0	37.5 \pm 1.8	18.2 \pm 1.7
11	16.8 \pm 1.4	41.8 \pm 1.4	39.5 \pm 1.8	20.1 \pm 1.6
12	17.5 \pm 1.9	43.8 \pm 2.3	40.8 \pm 1.6	20.5 \pm 1.4
13	18.4 \pm 2.3	45.8 \pm 3.5	42.7 \pm 2.3	21.3 \pm 1.6
14	19.0 \pm 2.6	47.3 \pm 4.5	44.1 \pm 2.7	21.8 \pm 1.5
15	19.6 \pm 2.7	49.6 \pm 5.0	44.5 \pm 2.8	22.7 \pm 1.7
				23.3 \pm 0.7

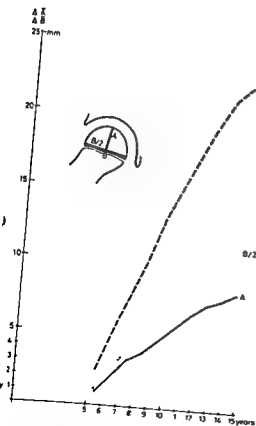


Figure 8 Growth rate of the osseous femoral head height (A), breadth (B) and half the breadth (B/2), respectively

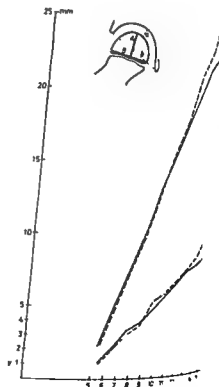


Figure 9 Growth in boys of the proximal femoral metaphysis (B) and the acetabulum (A)

increased by 32.62 per cent (from 2 mm^2 to 1607.68 mm^2) and the area of the whole ossification centre by 100 per cent (from 5744.10 mm^2 to 8574.29 mm^2). All this can, of course, be realized only by a great and intricate, but coordinated, growth activity. Upon examining the question from another side, even a rather small linear increase (or decrease) occasionally measurable on the radiograph, signifies a considerable change in the physico-physiological ossification rate.

In the period examined the growth rate in breadth of the femoral ossification centre exceeded that of its height (Figure 8). If we take into consideration that the height of the ossification centre augments only in one direction, namely in the surface, but that the breadth augments in two directions, i.e. from the two sides, then in this sense we could compare the growth of half the breadth ($B/2$) with the height, even then we found that the growth in breadth throughout the examined period exceeded by almost 40 per cent that of the height.

The above phenomenon may also be explained for the pattern of growth in breadth of the bony acetabulum (Figure 9). Radiographic examinations reveal that growth rate of the articulating ends is proportional and a similar growth rate is observed in the depth of the ossification centre of the femoral head and in the depth of the bony acetabulum. In the period of life examined, the growth rate of the breadth of the ossification centre and that of the acetabulum manifested an identical growth rate (Figure 9). An evaluable difference between growth in breadth of the acetabulum and that of the osseous part of the head may be observed only after the age at which age, with the formation of the upper bony acetabulum ossification centre at this site.

Differences in the ossification rate are observed in the breadth of the osseous part of the head and in that of the adjacent metaphysis (Figure 10). At the beginning of the period examined (5th year)

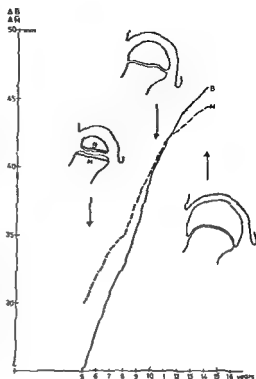


Figure 10 Average growth rate in breadth of the osseous epiphysis (B) and of the metaphysis (M) in boys

a smaller centre of the femoral head was seen above the metaphysis, later, owing to the more speedy ossification of the head, the difference in size gradually decreased and by about the 10th to 11th year the breadth of the metaphysis and that of the ossification centre of the femoral head were identical. The above growth rate difference also persisted after the 11th year, hence by the end of the examined period the breadth of the bony epiphysis exceeded that of the metaphysis.

There is a close connection between the increasing breadth of the proximal metaphysis and that of the epiphysis, as the rate of growth of both parts emerges from a common perichondral "Anlage". Upon comparing, in the examined period of life, the spatial increase of the osseous part of the subchondral growth plate of the metaphysis (circular area) with the augmented ossification surface of the epiphysis (hemispheric

surface) we found that with identical growth rate (30.62 per cent 30.62 per cent) the absolute spatial increase in the epiphysis was almost twofold that of the ossification area of the metaphysis. If, using the above-mentioned parameters, the breadth of the metaphysis and of the ossification centre of the femoral head increase from 28 mm to 32 mm, then the ossification surface of the metaphysis augments by 188.28 mm² and that of the ossification centre of the femoral head by 366.96 mm². Hence, with the increasing breadth of the femoral head its hemispherical form can be maintained only if growth of the epiphyseal surface also occurs at the above rate. If not the femoral head will become flattened and deformed.

The "articular space" discernible on the radiograph — that in the case of the hip joint depends mainly on the thickness of the cartilage covering the articulating bone ends — was of a different width in the so-called "weight-bearing zone" and medially in the area of the acetabular fossa in the course of the whole period of life examined. The picture characteristic of the adult acetabulum showed up only after the 13th year. In the area of the weight-bearing zone the articular space was of relatively constant size (6.0–5.5 mm), after the 13th year the width of the space decreased and with a mean value of 4.5 mm in the 15th year, closely approached at this stage the characteristic values of the adult hip joint. In the area of the acetabular fossa the width of the articular space did not decrease in a parallel manner, as a result of which the double-arched pattern of the acetabulum appeared.

Our investigation

Our investigations suggest that the rate of growth of the bone ends forming the hip joint has a slightly decreasing tendency. The slowing down of the growth of the femoral head is not as great as observed by Anderson et al (1963, 1964) but is fairly close to the findings of Kember & Sissons (1976). We did not find an adolescent

We did not find an adolescent growth spurt in the growth of the femoral head as is characteristic also of the longitudinal growth of the femur. The slowing down of the

growth of the femoral head occurs to our investigations, after the age of 11, whereas the same phenomenon is observed in the longitudinal growth of the femur after the age of 14 years (Lal 1963, 1964, Kember & Saxe 1962, Tupman 1962).

A feature different from the phenomena of growth in a growth of acetabular development between the 14 and 15 This can be explained by the conclusion of growth.

The growth rate of the bony epiphysis is to be different at different sites during growth of the acetabulum. The error for this phenomenon can be found in somewhat different growth curves of the cartilaginous and ossified epiphyses. The effect of local pressure and other factors (Trueta 1957).

The individual examination of each shows faster and slower growth periods, think that humoral regulating factors play a fundamental role in this process.

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RELATIONSHIP OF BONE MASS AND LOOSENING OF THE FEMORAL COMPONENT IN TOTAL HIP REPLACEMENT

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Parameters of bone mass in the upper end of the femur – the thickness of the calcar femorale and the pattern of the trabeculae – were evaluated in preoperative films of patients who had undergone total hip replacement. Patients with primary coxarthrosis rarely showed signs of osteoporosis, on the contrary, one of the parameters of bone mass was above average in the coxarthrosis cases. However, there was no difference, in the preoperative films, between hips that later went on to show signs of mechanical loosening of the stem prosthesis and hips that remained intact in this respect

Keywords arthroplasty, coxarthrosis, hip, osteoporosis

Accepted 11 vi 79

Mechanical loosening of the femoral component of the prosthesis following total replacement, unrelated to infection, is a common finding, even if serious clinical consequences so far seem to have been few (Jatz et al 1977, Beckenbaugh & Ilstrup 1977, Carlsson & Gentz, in preparation). In total hip replacement a gap forms between the prosthesis and the cement, usually first visible at the lateral edge of the prosthesis. It is believed that in addition to the load applied to the prosthesis, the positioning of the prosthesis and the distribution of the cement, the quality of the surrounding bone, and the pressure transmitted through the cement, are of importance (Amstutz et al

1977). However, osteoporosis appears to be rare in patients with primary coxarthrosis (osteoarthritis of the hip). On the contrary, Foss & Byers (1972), Roh et al (1973, 1974) and Carlsson et al (1979) found evidence of an increased bone mass in the upper limbs of patients with coxarthrosis.

The purpose of the present study was to evaluate the bone mass in the upper end of the femur by examining radiograms obtained before the surgical procedure, and to compare those patients who after total hip replacement showed signs of mechanical loosening with patients who did not develop this complication.

PATIENTS AND METHODS

Included in the study were 81 patients, 30 men, age 66 ± 6 , and 53 women, age 69 ± 7 , who had undergone total hip replacement because of primary coxarthrosis. The cases also fulfilled the criterion

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Figure 1 Separation between stem and cement observed 48 months after hip replacement according to Charnley. The loosening was not associated with any clinical symptoms

that the technical result was reasonably good, with the femur component of the prosthesis in an acceptable position and without defects in the surrounding cement. In 23 of the cases there was evidence of mechanical loosening between the cement and the metal stem, appearing as a radiolucent zone of 1 mm or more between metal and cement as measured on a standard antero-posterior view of the hip (Figure 1). The zone which was not present in the early postoperative period had a tendency to become wider as time passed.

Additional criteria to qualify for the study were that the preoperative radiogram was of sufficient quality to permit radio-morphometric evaluations and was without signs indicating secondary arthrosis.

The following variables were estimated in the preoperative radiogram



Figure 2 Cortical index, measuring the thickness of the calcar femorale

The cortical index

The thickness of the medial cortex proximal to the lesser trochanter was measured with calipers to a precision of 0.5 mm on an antero-posterior film of the hip (Figure 2). The measurement was divided by the width of the femoral neck at its narrowest part and the result between the two referred to as the cortical index (Fredensborg & Nilsson 1977). It was measured regardless of whether the hip was affected or not and the average

Singh's index

The trabecular pattern in the upper part of the femur was estimated on an antero-posterior film of the hips using the method of Singh (Figure 3).

Controls

For comparison of cortical and trabecular patterns, 10 apparently normal patients who had been referred for roentgen examination for reasons other than hip disease or femoral neck fracture were used (Fredensborg & Nilsson 1977).

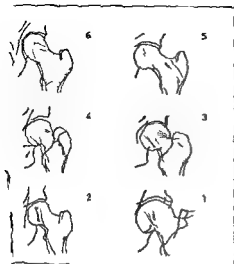


Fig. 3 Grading of trabecular pattern according to Singh's classification (by permission)

LTS

Cortical index was in most instances average in the coxarthrosis cases as compared with the controls (Figure 4). There was, however, no difference between the patients who after total hip replacement developed a gap between the metal and the bone and those who did not (Table 1).

Singh's index was in many instances difficult to evaluate because of structural changes, secondary to the coxarthrosis, in the end of the femur. Grades indicating osteoporosis were extremely rare. The hips were divided into two groups: normal (including Singh's grades 5 and 6) and abnormal (including all lower grades). There was no difference in distribution between the two groups: patients who subsequently developed loosening and patients who did not (Table 2).

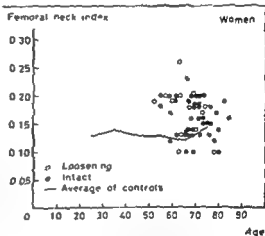
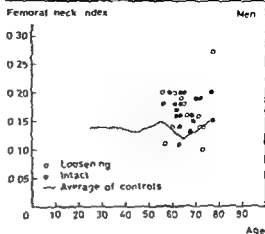


Figure 4 Cortical index of the hips in coxarthrosis patients compared with the average cortical index of 60 normal men and 60 normal women - 10 in each decade of age

DISCUSSION

The findings of the present study support the concept of osteoporosis as a condition that rarely coincides with coxarthrosis. Therefore the range of values of the parameters of bone mass in the upper end of the femur, measured

Table 1 Cortical index in intact hips and hips with signs of loosening ($\bar{x} \pm 1 \text{ s.d.}$)

		Men		Women
Loosening	(n = 19)	0.17 ± 0.03	(n = 42)	0.16 ± 0.04
	(n = 11)	0.16 ± 0.03	(n = 12)	0.16 ± 0.04

Table 2 Singh's index in intact hips and hips with signs of loosening

	≤4	5-6
Intact	6 M + 14 F = 20	13 M + 28 F = 41
Loosening	5 M + 2 F = 7	6 M + 9 F = 15

in the present study, was rather narrow and within this range the variation did not seem to be related to the resistance of the bone to pressure transmitted through the prosthesis and the cement. Not even the thickness of the calcar femorale appears to be of any measurable importance in spite of the significance this structure has been given in the discussion of mechanical loosening (Bocco et al 1977, Oh 1977). If the range is increased by including patients with multiple operations because of primary coxarthrosis or post traumatic necrosis our observations may not hold true but, then again, we have no means of evaluating retrospectively, the bone mass variables of the upper end of the femur in such patients.

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COSTS OF TREATMENT OF HIP FRACTURES

Calculation of the Consumption of the Resources of Hospitals and Rehabilitation Institutions

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A series of 518 patients with hip fractures and a median age of 78 years was followed for 6 months. On admission to hospital the patients were assessed and were found to be evenly distributed among four social function groups according to their level of dependence on the social welfare system. At the 6 months follow-up the mortality rate was about 16 per cent, leaving 437 patients for a reassessment of social function.

The average hospitalization time was 23 days, thus 17 per cent of all orthopaedic hospital beds in the area were occupied by patients with hip fractures. Patients staying the longest time in hospital were those waiting for discharge to a nursing home. The average stay in rehabilitation institutions was 71 days. The total rehabilitation course was longest for the most dependent patients.

The risk of death or deterioration of social function among patients admitted from home was 48 per cent. In the case of social deterioration or technical failure following the fracture treatment the total rehabilitation course was considerably prolonged.

The resources required for the treatment of hip fractures in a suburban area of 500 000 inhabitants were calculated to be 32 hospital beds, 43 rehabilitation beds and at least 21 nursing home beds.

Key words: fractures, rehabilitation, femoral neck fractures, rehabilitation, hospitalization.

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Technical results of the treatment of hip fractures have been well described, but less attention has been made to clarify the social consequences of the treatment (Campbell 1976, Cobey et al 1976, Jensen et al 1979, Katz et al 1967, Lindberg & Stevens 1974).

Although the number of hip fractures is increasing in the Western countries due to an increasing average age of the population (Campbell 1976, Ceder 1977, Jensen & Tøndevold, in press, Lindberg & Sjøstrand 1977, Mårtensson 1962), there have been very few studies of the social and economical aspects of the treatment of these fractures.

The purpose of the present study was to evaluate the relation between the costs of the treatment of hip fractures and the efficiency of the social rehabilitation.

PATIENTS AND METHODS

During the period January 1st to December 31st 1977 a total of 518 patients with hip fractures were admitted to three different orthopaedic units covering a suburban area with a population of 500 000 inhabitants. The median age of the patients was 78 years (range 26-96) and 80.5 per cent (417/518) were females.

Table 1 Treatment of 518 patients with hip fractures

	Femoral neck fractures	Trochanteric fractures
Sliding nail	62 (27.8%)	
Hemiarthroplasty	117 (52.5%)	
Non-operative	44 (19.7%)	3
* Nail plate		154 (52.2%)
Sliding screw plate		131 (44.4%)
Others		7
Total	223	295

* The nail plates were of the Jewett or McLaughlin type

Femoral neck fractures were recorded in 43.1 per cent (223/518) of the cases and trochanteric fractures in 56.9 per cent (295/518). The fractures were treated as listed in Table 1.

The physical rehabilitation programme involved 6 weeks of partial weight bearing mobilization in both unstable trochanteric fractures treated by

all other cases. When the rehabilitation programme did not progress satisfactorily within the first 2 weeks the patients were discharged either to a convalescent home with facilities for physical therapy (Skodsborg Sanatorium) or to a true rehabilitation clinic (Esbenderup Hospital or Trancheven) with a highly developed socio-medical care system. The choice of institution depended on the municipal address of the patient.

The patients were discharged from any of these institutions as soon as they were able to walk and undertake activities of daily living.

On admission to hospital the patients were classified into social function groups (Stevens 1974) according to their degree of dependence on the social welfare system, as defined in Table 2.

The patients were followed for 6 months and a reassessment of the area was made. The mortality among the patients studied and also the time spent in both the rehabilitation clinics or the convalescent homes were also considered.

RESULTS

The pre fracture classification of function of the total case material patients is recorded in Table 3. There was a fairly even distribution among the groups.

The patients in groups I, II and III were all admitted from home as well as one patient placed in group IV. A total of 383 (51.8%) of the patients were admitted from home whereas 25.9 per cent (134/518) were nursing home patients at the time of fracture and one patient was admitted to the rehabilitation clinic.

The hospital mortality among patients admitted from home was 6.0 per cent (23/383) with an average hospital stay of 28 days compared with 13.4 per cent (7/134) with a hospitalization time of 28 days among patients from nursing homes. Mortality rates 6 months after fracture were 11.3 per cent (43/383) among patients admitted from home and 24.4 per cent (9/134) among patients from nursing homes.

Table 2 The assessment of social function

	Social function groups	Definition
I	Independent	Manages everything Possibly working
II	Slightly dependent	Manages household Meals-on wheels, Home-help ≤ 4 hours week
III	Moderately dependent	Manages personal needs Home-help ≥ 5 hours week Possibly District Nurse
IV	Totally dependent	Living in nursing home or long term nursing at home

among patients admitted from homes
 placement of the patients after discharge from hospital related to the pre-fracture social function groups is illustrated in Figure 1. We found that 8.9 per cent (32/360) of patients admitted from home were discharged to a nursing home, while 29.7 per cent (107/360) returned directly to their homes. Another 33.3 per cent (120/360) of the patients were discharged to the convalescent homes and 28.3 per cent (102/360) to the rehabilitation clinics. There was no significant difference in the composition of social function groups of the patients discharged to the four groups ($P=0.64$, Chi-square test). Two patients assigned to group IV were discharged to nursing homes; they were admitted from, viz their own homes and a rehabilitation clinic, respectively. The average hospitalization time was 22.7 days. The total consumption of hospital days for the 518 patients amounted to 11,774 hospital days, which is equivalent to 32.1 beds. This means that in the present area of 500,000 inhabitants 173 per cent of all orthopaedic hospital beds were consumed for the treatment of hip fractures. Patients in group I pre-fracture stayed an

average of 22.8 days in hospital compared with 30.4 days for patients in group II and 33.3 days for those in group III. There was thus no significant difference ($P>0.05$, Kruskal-Wallis test) in the consumption of hospital resources for these three social function groups. The nursing home patients in group IV were in hospital for only 6.9 days on average, which equals 8.0 per cent (938/11,738) of the total number of hospital days.

The placement of the patients after discharge from hospital related to the consumption of hospital resources is illustrated in Figure 2. Patients discharged to the convalescent home stayed 15 days less in hospital than those discharged to their own home and 13 days less — or only about half of the time — than those discharged to the rehabilitation clinics ($P<0.0001$, Kruskal-Wallis test). The longest stay in hospital of 55.4 days was encountered in patients who were waiting for a place in a nursing home and they consumed 16.5 per cent (1,774/10,784) of the total number of hospital days for the surviving patients. The patients who were discharged to the convalescent home remained there for an average of 6.4 days compared with 78.3 days for those discharged to rehabilitation clinics ($P<0.05$, Kruskal-Wallis test).

A total of 15,713 institution days were needed for the rehabilitation of patients with hip fractures. This equals 43 institution beds in our area of 500,000 inhabitants. The costs

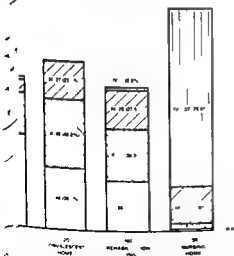


Figure 1 Placement after discharge from hospital related to pre-fracture social function groups in patients with hip fracture

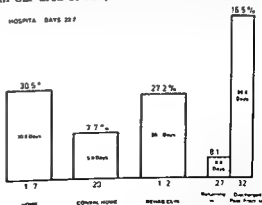


Figure 2 Placement after discharge from hospital related to consumption of hospital resources

Table 3 The deterioration of social function and the mortality 6 months after fracture

Pre-fracture assessment into social function groups	Social function groups at 6 months follow-up						Total
	<	No of deaths	I	II	III	IV	
I	148	4 (2.7%)	92 (63.9%)	34 (23.6%)	16 (11.1%)	2 (1.4%)	144
II	128	12 (9.4%)		66 (56.9%)	32 (27.6%)	18 (15.5%)	116
III	106	27 (25.5%)			40 (50.6%)	39 (49.4%)	79
IV	136	38 (27.9%)				38	98
Total	518	81 (15.6%)	92 (21.1%)	100 (22.9%)	88 (20.1%)	157 (35.9%)	525

per day at the convalescent home are about 60 per cent of the costs at the rehabilitation clinics. The average stay in the institutions was 70.8 days. The patients classified pre-fracture into group I stayed in the institutions for 63.9 days on average, whereas the comparative figures for patients in group II were 69.7 days and in group III 80.6 days ($P < 0.05$, Kruskal-Wallis test).

A reassessment of social function 6 months after the fracture was made in the 437 surviving patients. Of these 340 were admitted from home. The results obtained at the follow-up are shown in Table 3. Among the surviving patients admitted from home 17.4 per cent (59/340) had become nursing home patients. The risk of death was found to increase with the level of social dependence on admission.

Among the patients in group I pre-fracture 63.9 per cent (92/144) of the survivors maintained their social function compared with 56.9 per cent (66/116) in group II and 50.6 per cent (40/79) in group III. At the 6 months follow-up the average risk of deterioration of social function among surviving patients admitted from home was thus 41.5 per cent (141/340) and the total risk of death or deterioration among patients admitted from home was 48.0 per cent (184/383). In a statistical analysis of these data the total risk of death or deterioration was found to increase significantly with a higher level of dependence as assessed on admission to hospital ($P < 0.05$, Chi-square test).

The results of the follow-up assessment of

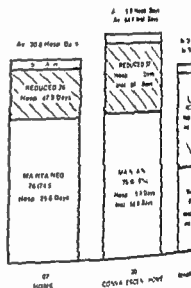


Figure 3 Placement after discharge after hip fracture related to resources (hospital and nursing home) at the 6 months follow-up

social function were also analysed in relation to the consumption of resources at home and in institutions, as illustrated in Figure 3. Among the surviving patients discharged to their homes 74.5 per cent (51/67) maintained their social function with a consumption of 25.8 hospital days. In case of deterioration of social function the average hospitalization time was almost doubled.

Among 120 patients discharged to the convalescent home 115 patients were assessed at the follow-up. Of these 67.8 per cent maintained their social function and stayed an average of 15.4 days in the institution. The average stay in the rehabilitation course was thus 15.4 days.

of deterioration of social function the course was 103.8 days on average. Of the patients discharged to the institution clinics 98 survived the 6 month follow-up. The social function was maintained in 46 per cent (46/98) with an average of 105 days in hospital and 67.9 days in institution, or a total rehabilitation course of 173.4 days. When the social function was found to have deteriorated the total rehabilitation course was 117.7 days. Thus the risk of deterioration of social function was significantly higher ($P < 0.05$, Chi-square test) in patients discharged to the rehabilitation clinics although the rehabilitation course was considerably longer.

The significance of technical failures following the treatment of hip fractures as a factor in the consumption of resources and the final result was analysed. Technical failures following the treatment of femoral fractures were encountered in 15.2 per cent (22/145) of the cases. This figure was significantly influenced by a high failure rate after nail fixation (19/62 = 30.6 per cent). There was no significant correlation between technical failures and the pre-fracture social function groups.

The total consumption of resources, as shown in Figure 4, was, however, considerably increased in cases of technical failure ($P < 0.0006$, Mann-Whitney test) as patients consumed an average of 31.4 hospital days (34/223 patients) and 80.1 institution days (19/90 patients), respectively, compared with 19.5 hospital days (189/223 patients) and 61.5 institution days (71/90 patients) in uncomplicated cases. The risk of deterioration of social function among survivors was 51.5 per cent (17/33) following technical failures, which is significantly higher ($P < 0.05$, Chi-square test) than the 27.3 per cent (4/16) risk in uncomplicated cases. Following the treatment of trochanteric fractures there was a technical failure rate of 17 per cent (17/295) predominantly following internal fixation with the nail-in apparatus (12/124 = 9.7 per

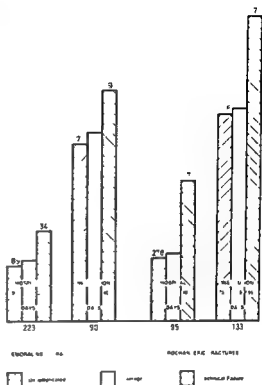


Figure 4 Consumption of resources related to technical failures following the treatment of hip fractures

cent). There was no significant relation to the pre-fracture social function groups.

In the case of technical failure the consumption of resources was on average 48.9 hospital days (17/295 patients) and 105.9 institution days (7/133 patients) compared with 22.1 hospital days (278/295 patients) and 72.1 institution days (126/133 patients) in uncomplicated cases ($P < 0.05$, Mann-Whitney test). The risk of deterioration of social function among survivors following technical failures in this group was 37.5 per cent (6/16). In uncomplicated cases 67.5 per cent (154/228) of the survivors maintained their social function. Social deterioration was thus not related to technical failure in trochanteric fractures ($P > 0.05$, Chi-square test).

DISCUSSION

Devas (1974) emphasized that loss of function in the elderly means loss of independence, which is disastrous for the patient and expensive for the community. It has been estimated in previous studies (Cobey et al 1976, Katz et al 1964 and 1967) that only 25–50 per cent of patients with hip fractures maintain their level of function, when walking ability and activities of daily living are considered. An assessment system containing this information obviously gives some indication of the quality of life.

It was our wish to apply an assessment system, which not only considered the dependence of the patient but also took into account the demands on the social welfare system and thereby the expenses for the community. We therefore found the assessment system described by Thomas & Stevens (1974), with some modifications, to be more suitable. In accordance with the results stated by Thomas & Stevens (1974) we found that nearly 60 per cent of the surviving patients, who were admitted from home, maintained their social function. The value of the assessment system applied is discussed in detail in the companion paper (Jensen et al 1979).

Little is known about the consumption of the resources of hospitals and rehabilitation institutions in the treatment of hip fractures. One of the major problems in treating these elderly patients is the placement of the patients following the necessary hospital care. In our series from a suburban area of 500,000 inhabitants 62 per cent of the patients admitted from home were discharged to a convalescent home or to rehabilitation institutions. This agrees well with the figures given in other studies where 40–60 per cent of patients were discharged to institutions (Campbell 1976, Ceder et al 1977, Gylling 1960).

There is in our opinion no doubt that the possibility of transferring the patients to some sort of rehabilitation institution means a reduction in hospitalization time. In the present series we found in accordance with

others (Ceder et al 1977, Tondevold, in press) an average hospitalization time of 23 days, which can be reduced further for this category of patients. For comparison McCown & Miller (1976) 23 days, Riska (1970) 30 days, Kerner (1976) 28 days and Schenk et al (1975) 24 days in hospital, but the final results of the present series lacked clarification. In the present series, however, it is important to know the rehabilitation course as the success of a reduction in hospitalization time is the result is a high intake of the nursing homes a few months later. In our series Ødegård & Unsgård (1978) 44 per cent of patients were discharged directly to nursing homes from hospital and in Campbell (1976) about 30 per cent of patients were discharged to nursing homes 4 months after the present series less than 9 per cent of patients admitted from home went directly to nursing homes, and a total of 10 per cent of the patients were found to be discharged to nursing homes 6 months after the fracture. Our results agree well with those of others (Ceder et al 1977, Clark & Warner 1977, Gylling 1960).

The establishment of such a rehabilitation institution is a political question for the local authorities. In our area the costs of running a convalescent home with facilities for physical therapy are only about 60 per cent of the costs of a rehabilitation clinic with a modern developed socio-medical rehabilitation programme and only about 33 per cent of the costs of an orthopaedic hospital bed. The costs of a rehabilitation clinic bed are about 40 per cent of that of a hospital bed.

The problem to be discussed is not the establishment of institution is most suitable for the rehabilitation of patients with hip fractures. In this series we found that the cost of hospitalization in terms of days was 14 less in the convalescent home than in the rehabilitation clinics and that the patients had to wait an extra 13 days in the hospital before being admitted to the rehabilitation clinics. The difference in the composition of the function groups of the patients at the

these institutions. At the 6 months, however, 68 per cent of the from the convalescent home had and their social function compared per cent of the patients from the rehabilitation clinics. The rehabilitation used 11 more days than the convalescent home for the maintenance of social but only 4 more days were used in the convalescent cases. It seems quite possible that the highly developed socio-medical care in the rehabilitation clinics leads, on the part of the patients, to a much greater dependence on home-help and meals-on-wheels. It is an open question whether this level of dependence increases the quality of life. From a purely economic view, the convalescent homes with facilities for medical therapy seem to be quite sufficient for the rehabilitation of patients with hip fractures.

Another essential problem to be considered is the cost of technical failures following the treatment of hip fractures. It has recently been pointed out (Jensen & Tøndevold, in press) that technical failures considerably increase the hospitalization time. In the present series we found that technical failures during the treatment of femoral neck fractures involved 12 extra hospital days and 4 extra nursing days. The comparative figures for Charcot fractures were an additional consumption of 27 hospital days and 34 nursing days. This strongly illustrates the importance of applying the safest possible method of treatment because failure at least for femoral neck fractures, also involves an increased risk of social deterioration. In conclusion, we found that the consumption of hospital resources and those of rehabilitation institutions for the treatment of hip fractures is rather high. In a suburban area with 500 000 inhabitants 32 hospital beds and 17 rehabilitation beds were needed. This amounts to 17 per cent of the total number of hospital beds for orthopaedic surgery in the county. With the increasing number of hip fractures a further increase can be expected. We also found that the risk of death or

deterioration of social function among patients admitted from home was about 48 per cent during the 6 months following the fracture.

Bearing these results in mind the goal of the treatment of hip fractures is to apply the method which with the smallest consumption of resources leads to the safest technical results and maintains at the same time the social and functional independence of the patients to the highest degree.

The results of our experiences can obviously not be directly applied either to a rural district or to a country with a different social complexity. Considering however, the economic crisis which every health system must face in the years immediately ahead, we feel that there is a need for comparable studies of the kind presented here.

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ARTHROSCOPY OF THE PATELLO-FEMORAL

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Arthroscopy of the knee joint was performed in 126 patients complaining of symptoms in the patello-femoral joint. In about one-third of these cases the arthroscopic findings in the patello-femoral joint were normal whereas the remainder had varying degrees of chondromalacia or arthrosis. The classification of changes agreed well with an independent classification carried out in conjunction with surgery. In one-third of the cases there were additional findings which could explain the knee symptoms more than half of these being degenerative changes reminiscent of an early gonarthrosis located in the femuro-tibial joint. There were no complications arising from the arthroscopy procedure which was well tolerated by the patients. It is concluded that arthroscopy is a helpful tool for differential diagnosis in patients with patello-femoral pain and for classification of degenerative changes in this joint.

Key words: arthroscopy, chondromalacia, knee joint, osteoarthritis, patella.

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Edge & Dunlop (1975) concluded that physical techniques are not very helpful in the diagnosis or classification of chondromalacia in the patello-femoral joint. Chondromalacia is basically a pathological diagnosis which can be obtained only by inspection of the joint. A number of authors (Casscells 1971, Eikelaar 1975, 1973, 1974, Henry 1973, Jackson 1973, Johnson 1974, Overbridge & Dunlop 1974, Watanabe et al 1969, Watanabe 1974, 1973) have reported that the patello-femoral joint can be successfully explored by arthroscopy. The purpose of this paper is to describe the diagnostic efficacy of arthroscopy in patients with patello-femoral pain.

Support was obtained from the Swedish Research Council (project no B-2737-09B) and the Greta and Johan Alfred Osterlund Foundations.

MATERIAL & METHODS

Patients

Included in the study were 126 patients, 64 women and 62 men. The age distribution is shown in Figure 1.

The criteria of patello-femoral involvement were two or more of the following symptoms:

Retro-patellar pain with or without disseminated pain in the knee joint

Locking of the knee

Also two or more of the following physical findings were required:

Retro-patellar crepitations

Tenderness when pressing and moving the patella

Tenderness when tapping the patella

Tenderness along the medial edge of the patella

In none of these cases was there any suspicion of recent trauma to the knee joint.

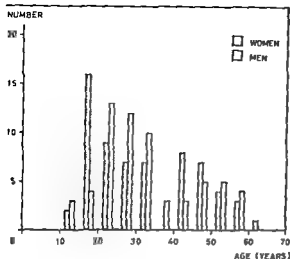


Figure 1 Age and sex distribution

Equipment

The Storz arthroscope was used. The diameter of this arthroscope is 5 mm and it is supplied with two wide-angle telescope lenses with an angulation of 30° and 70°, respectively. Also, the Storz fibre light source was used. In 32 cases intra-articular photographs were obtained, using the Storz endo-camera and flashlight.

Procedure

The arthroscopy was performed under general anaesthesia with a tourniquet on the thigh. The procedure was carried out in a sterile field after preparations identical to those of an arthrotomy. Either by continuous infusion or by initial injection of about 100 ml of isotonic sodium chloride solution, the knee joint was distended. In the latter case, the liquid was replaced when needed. Methylthionine was added to the liquid to improve the contrast effect. The incision for the arthroscope was usually 1 cm lateral and/or medial to the patellar tendon. Both lenses were usually required. All the studies were done on ambulatory patients. In all of these cases not only the patello-femoral joint was inspected, but a complete arthroscopic examination was carried out. There were no complications arising from the arthroscopy procedure.

Classification

The findings in the patello-femoral joint were classified as follows:
Normal Blue-white flawless patella cartilage, fitting exactly into the patello-femoral groove.



Figure 2 Example of chondromalacia III. 32-year old man with recurrent femoral symptoms for 11 years. Fine and deep fissures, most of the patella surface is involved.
 Upper: Photogram obtained through arthroscope.
 Lower: Operative finding.

Chondromalacia (Outerbridge 1942)

- Grade I Light brown-yellow discoloration of the articular cartilage yields to the end arthroscope or to a finger, but no fragmentation or erosion.
- Grade II Fragmentation and fissures of area of 13 cm or less. The lesion was estimated by the patella surface with the knee in extension.
- Grade III Fragmentation and fissures of area of more than 13 cm.
- Grade IV Erosion of the articular surface to the subchondral bone cannot be distinguished from the femoral arthrosis (Femoral).

Also post-traumatic and degenerative changes of the intra-articular structures and lamina synovialis, were recorded.

cedures for the treatment of chondromalacia patellae

RESULTS

The patello-femoral joint

A grading of the presence and degree of chondromalacia patellae showed that 34 per cent of the cases were normal in this respect whereas 37 per cent had varying degrees of chondromalacia grade I–III. In an additional 29 per cent there were changes of grade IV, indistinguishable from arthrosis of the patello-femoral joint (Table 1). The latter group, both men and women, were significantly older—about two decades—than the other cases ($P < 0.001$) (Figure 4). Women with normal patello-femoral joints were significantly younger than women with chondromalacia of grades II and III ($0.05 > P > 0.02$).

Other findings

In no less than 35 per cent of the patients there were findings outside the patello-femoral joint which could be suspected to produce pain (Table 2). In 24 joints there were signs of degenerative changes which could be interpreted as gonarthrosis in the tibio-femoral joint. These patients were significantly older than the remaining cases ($P < 0.001$) (Table 2). All but five of the cases with changes resembling gonarthrosis also had grade IV changes in the patello-femoral joint. The distribution of changes between the three articulations of the knee joint is demonstrated in Figure 5.

In another 20 joints there were altogether 28 pathological findings as described in Table 3.

Table 1 Age, sex and distribution in grades of chondromalacia patellae (Number/age, average \pm s.d.)

	Normal	Chondromalacia patellae			
		Grade I	Grade II	Grade III	Grade IV/arthrosis
Men	31/16 s 11/21 7	1/6 2/6	1/4 s 6/11	11/27 7 14/27 9	11/49 9 16/50 9

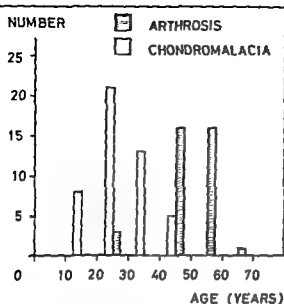


Figure 4 Age distribution of patients with arthrosis and chondromalacia

Table 2 Arthroscopic findings in the knee joint outside the patello femoral joint (Number/age average \pm s.d.)

	Degenerative changes	Other
Men	11/34 12	10/27 8
Women	15/47 8	10/30 16

Confirmation at surgery

The classification of patello-femoral changes was repeated in conjunction with the surgical procedure. The grade of changes in the patello-femoral joint was confirmed in all

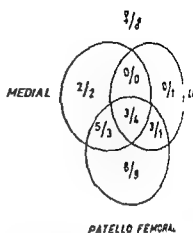


Figure 5 Distribution of degenerative changes in the various compartments of the knee. chondromalacia patello femoral excluded

but four of the 58 joints. In one originally classified as normal, the \bar{C} was changed to chondromalacia grade I. Two patients were changed from grade I to II, and finally one from grade II to femoral arthrosis—to normal. In all instances the other findings were confirmed at surgery. All the injuries were verified. In one case, classified as normal in the medial femoral condyle, medial arthrosis was found at surgery. Osteochondral fractures of the patella were diagnosed in two cases, neither of which could be confirmed at surgery but were classified as chondromalacia grade II and III, respectively. In one case originally classified as a chondromalacia grade

Table 3 Other arthroscopic findings and their coincidence with chondromalacia patello femoral

	Normal	Grade I	Grade II	Grade III	Grade IV
Torn medial meniscus	3			1	3
Torn lateral meniscus	3		1		
Ruptured anterior cruciate ligament	1				
Plica fibrotica synovialis	2	1		1	1
Rheumatoid arthritis				1	
Osteochondral fracture	1				
Meniscus discoides	1				1
Loose bodies	1				
Morbus Hoffa	5	1			

changes suggestive of osteochondral were also found

SSION

one-third of the cases, changes in other than the patello-femoral joint found. Chondromalacia patellae and patello-femoral processes may be seen for lesions of the medial semilunar (Outerbridge & Dunlop 1975, Smillie 1975). Obviously, the reverse is also true. It is believed to have a chondromalacia indeed found to have lesions of the articular cartilages with or without visible changes in the patello-femoral joint. Plica synovialis (Watanabe 1974) was found in four cases. This is a fibrous string which originates on the anterior aspect of the femoral condyle, crosses the edge of the femur condyle and breaks up into diverging portions which continue into the fibrous capsule. In the use of the tourniquet, an evaluation of the condition of the lamina synovialis was possible. However, synovitis was frequently found in conjunction with gonarthrosis. There were no synovial changes suggestive of infection, chondromatosis or villonodular synovitis. Biopsy or arthroscopy was not undertaken in twenty-five patients—19 per cent—where pathological findings at arthroscopy were in contrast to Leslie & Bentley (1977), who found normal joints in 49 per cent of the joints examined with arthroscopy because of suspicion of chondromalacia patellae. The authors therefore suggested that the signs were more helpful in the diagnosis. The age of the 25 patients without arthroscopy was 25 ± 8 and 22 ± 5 for men and women respectively. Among these patients there were slightly but not significantly more than the chondromalacia cases, there were six with signs of synovitis, discoloration and hypertrophy. Changes suggestive of early gonarthrosis, such as fibrillation and erosion—were found in the femuro-tibial joint in no less

than 24 of the patients and at about two decades earlier in life than the usual age for the initial examination of patients with gonarthrosis (Hernborg & Nilsson 1977). The localization differed to some extent from that usually found in primary gonarthrosis there being less preponderance for the medial aspect of the joint (Hagstedt 1974). In the older of the arthroscopy patients, half or more of the cases had such changes. Since the accumulated risk of gonarthrosis in the city of Malmö barely exceeds 5 per cent (Danielsson & Hernborg 1970) two possibilities must be considered. Either pain in the patello-femoral joint is a sign, early in life, indicating that the patient will develop gonarthrosis later on or we are dealing here with degenerative changes of the cartilage, unrelated to gonarthrosis in its generally accepted sense.

Arthroscopy is a valuable tool for the diagnosis of degenerative changes in the joint. Arthrotomy and direct inspection of the patella appears to add little further information. It should be noted however, that the selection of the 58 patients for arthrotomy in this study was usually based on pathological arthroscopy findings in the patello-femoral joint or elsewhere, whereas completely normal joints were rarely operated on. False negatives therefore cannot be entirely ruled out.

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RESULTS AFTER MENISCECTOMY IN 147 ATHLETES

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The object of this study was to ascertain the consequences of meniscectomy performed because of meniscus injury sustained during sports. Out of 147 athletes meniscectomized from 1964 to 1973 a total of 142 were seen at follow-up. The median follow-up period was 4.25 (range 0.25-11.0) years. During the follow-up period 8 per cent (11/142) had further surgical treatment because of new knee injuries. At the time of follow up, 15 per cent (20/131) of the patients who had undergone operation solely for the primary meniscus injury had given up sports because of knee complaints and 12 per cent (16/131) had restricted their sporting activities. There were no complaints in 46 per cent (60/131). In 79 per cent (56/71) of the patients who had complaints, these had started immediately after operation. The main trouble was a feeling of instability and pain on weight-bearing. The complaints correlated with the physical findings at follow-up. In 14 per cent (18/131) there was increased collateral instability of the knee. Considering also previous experimental studies, it is concluded that meniscectomy causes immediate functional changes in the knee which explain the complaints. There was no correlation between complaints and radiological osteoarthritis.

Key words: athletic injuries, meniscectomy, osteoarthritis

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Injury to the knee is a dreaded athletic injury, which is often followed by persistent knee complaints in spite of early diagnosis and treatment (Appel 1970, Christopherson & Leard 1970, Jacobsen 1977). The incidence of knee complaints is definitely higher among athletes - especially football players - than among non-athletes who do not participate in sports (Appel & Andersson 1977). Injury to the meniscus is the most common type of injury sustained by athletes (Andersen & Christensen 1959). In analyses of meniscectomized patients between 28 and 69 per cent of the patients with knee injuries are reported to have been injured in sports (Appel 1970, Bestle 1955, Christensen & Crasselt 1973, Johnson et al 1973, Parry et al 1958, Percy 1962,

Rothascher 1960), and this indirectly confirms that injury to the meniscus is common among athletes.

The late results of meniscectomy have varied from one analysis to the other, presumably because of differences in the materials, diagnostic methods, and systems of grading complaints and physical findings. In previous studies no distinction was made between athletes and non-athletes. However, the former differ in that they have a younger mean age, and they make greater demands on the knee in connection with continued athletic activities.

The present analysis was designed to investigate the consequences of removing a meniscus from an otherwise normal knee in

athletes, assessed in terms of subjective complaints and physical and radiological findings

PATIENTS AND METHODS

During the period 1964-73 meniscectomy was performed on 439 patients in the Department of Orthopaedic Surgery T-3, Gentofte Hospital, Copenhagen. The analysis is based upon the 147 patients who had sustained athletic injury to one meniscus in an otherwise normal knee. Out of these patients 142 were seen at follow-up in 1975. Two had emigrated, one had died, and two could not be traced. The operative technique was according to the principles of Smillie (1970). Postoperatively quadriceps exercises were started not later than 24 hours after the operation. When the patients could lift the extended leg, weight-bearing with extended knee was permitted until the sutures were removed on the 10th day, and thereafter the patients were trained in knee-bending and exercises against resistance.

The median age at operation was 25 years, range 14 to 56 years. The ratio males to females was 6:3, right to left-sided injuries 1:0:3 and medial to lateral injuries 5:7. Six patients underwent partial and all the others total meniscectomy.

Follow-up examination performed by two of the authors consisted of an interview, a physical examination, and radiography of both knees. The follow-up period, defined as the period from meniscectomy to the follow-up examination, ranged from 2 years 3 months to 11 years, median 4 years 3 months. The median length of the history, defined as the time from the athletic

injury or from the onset of the first operation, was 6 months (range 0-14).

Table 1 shows the branches and level pursued by the patients when the injury was sustained.

Complaints were assessed according to a system and included the following: 1 point for swelling of the knee, 1 point for getting up and down stairs, 2 points for walking, 3 points for pain on weight-bearing, 4 points for locking, 5 points for rest pain, 6 points for symptoms giving 0 points and the total symptoms 21 points.

The physical examination of the knee included six parameters (Table 1). Effusion was defined as a sign of patella tap on the condyle. More than 5° reduction in range of motion as compared with the opposite knee was reduced mobility. Collateral medial drawer sign, and tenderness in the joint were assessed in relation to the opposite knee. Of the quadriceps muscle was defined as reduction of more than 2 cm in the circumference of the thigh, measured 10 cm above the patella, in relation to the good leg.

Radiography comprised an anteroposterior and lateral views of both knees, with and without weight bearing. The focus-film distance was 100 cm. The radiologist read the films without knowledge of the results of the other investigations. The presence of degenerative changes in the femur was according to the principles of Kellgren. Osteoarthritis was defined as narrowing of the joint space and/or changes of the bone in the form of sclerosis or cyst formation. The joint was narrowed if (1) it was less than half the width of the corresponding joint compartment or (2) it was less than half the width of the corresponding joint compartment.

Table 1 Type of sport being pursued at the time of injury (n = 147)

	Level of athletics ^{a)}		
	Top	Competitive	Recreational
Football	17	48	15
Handball + basketball	6	14	3
Gymnastics	0	1	8
Athletics	3	2	2
Badminton	1	4	0
Swimming	1	1	2
Others	1	2	10
	29	73	40

^{a)} Top: Tournaments in the 1st and 2nd division or a higher level.
Competitive: Official tournaments at a lower level.
Recreational: Others.

ii) it became narrower when the patient standing or (iii) it was less than 3 mm in. In addition, marginal osteophytes and g of the femoral condyles were recorded (K 1948)

2 cases preoperative routine films of the knee were available. These films were read in the same way as described above.

Statistical methods

Parametric statistical tests were used. In the tests of complaints the patients were grouped according to individual score.

Results

Postoperative complications

One patient developed pyarthrosis, one deep phlebitis, and one a wound infection. There were no late sequelae of these complications at follow-up. One patient developed chronic synovitis, which was later treated by arthroscopy. Puncture of the knee for diagnostic effusion was carried out in 50

Injuries in the course of the follow-up

During the follow-up period 8 per cent (8/131) (95 per cent confidence limits 4–14 per cent) had operations on the knees because of their injuries, five of which were due to recurrent athletic activities. Three sustained injuries to the operated knee (one ligament tear and two meniscus injuries) and eight to the unoperated knee (two ligament tears and nine meniscus injuries).

The analyses to be reported below concern only the 131 patients who had undergone meniscectomy solely for the primary meniscus

Restrictions in athletic activities

Ten per cent (20/131) had given up all athletic activities because of the complaints after meniscectomy, while 12 per cent (16/131) had restricted their activities by

pursuing sports at a lower level and/or changing to a less vigorous branch of sport.

The 27 per cent (36/131) (95 per cent confidence limits 20–36 per cent) with altered sports activities had significantly more subjective complaints than those whose activities were unchanged ($P < 0.002$, Mann-Whitney test). Sex, age, branch of sport, level of sport, and site of the injured meniscus had no influence ($P > 0.7, 0.4, 0.8, 0.6$, and 0.05 , respectively, χ^2 tests).

Complaints

Table 2 lists the incidence of the individual symptoms. The distribution of the scores for complaints (Figure 1) shows that 46 per cent (60/131) reported no complaints, while 12.2 per cent (16/131) had a score of ≥ 10 . Only one patient had started on another job because of knee complaints.

In order to screen for prognostic variables, the distribution of the scores in various subgroups was compared (Table 2). Neither age at operation, length of history, branch of sport, level of sport, postoperative effusion, nor the localization of the injured meniscus had any significant influence. On the other hand, women had significantly more complaints than men.

There was no correlation between the length of the follow-up period and the score for complaints, although there was a tendency for patients with a short follow-up period to have more complaints than patients with a long follow-up period. The two groups of patients, with a short and a long follow-up period, were considered comparable, as the above-mentioned variables were equally distributed in both groups (all P values > 0.2).

The complaints had been present in 79 per cent (56/71) since the operation.

Physical findings

The frequency of abnormal findings compared with the severity of complaints is apparent from Table 3. In 62 per cent (81/131) there were no abnormal findings,

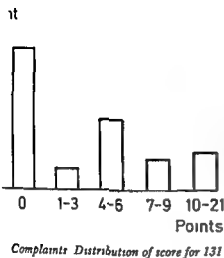
Table 2 Complaints in the various groups of patients

	Total	Women	≤ 25 years	History ≤ 6 months	Football players	Recrea- tional	Effusion postop	Lateral meniscus	Follow up ≤ 47 months
Number of patients	(no)	18	72	65	73	90	44	20	63
Swelling of the knee	(%)	33.3	25.0	20.0	21.9	22.2	22.7	20.0	17.5
Complaints on walking stairs	(%)	33.3	12.5	15.4	9.6	27.8	22.7	10.0	12.7
Sensation of instability	(%)	20.6	23.6	13.9	16.4	27.8	25.0	15.0	22.2
Pain on weight bearing	(%)	38.2	38.9	30.8	31.5	38.9	43.2	35.0	47.6
Episodes of locking	(%)	6.1	6.9	4.6	5.5	5.6	4.6	5.0	11.1
Rest pain	(%)	22.2	9.7	12.3	8.2	13.9	9.1	0.0	14.3
Median score		4	2	0	0	3	4	0	4
P value		0.04*	0.6*	0.95**	0.3*	0.7***	0.26*	0.45*	0.1**

* Mann Whitney U test

** Spearman rank correlation test

*** Kruskal Wallis test



patient had more than three. There definite correlation between the of abnormal findings and the score of

raphy

ng the 102 patients for whom pre- te films of the operated knee were le two had marginal osteophytes at the the injured meniscus, but all the others changes

asures of the non operated knee at up showed that five patients had ial osteophytes, two narrowing of

the joint space, and one osteochondritis. In 95 per cent (125/131) the radiological appearances were normal. Forty per cent (53/131) had no radiological changes on the operated side at follow-up. The changes in the other patients are illustrated in Table 4.

Osteoarthritis according to the criteria of Ahlback was present in 30 patients, 26 of whom had narrowing of the joint space, two sclerosis, and two both of these signs. In addition, loose bodies were found in eight and osteochondritis in five.

As compared with changes in the control knee, there was a significantly higher incidence of changes in the operated knee ($P < 0.001$, sign test).

There was no correlation between the length of the follow-up period and the presence of radiological changes ($P > 0.5$, χ^2 test).

The degree of complaints showed a significantly positive correlation to the number of Fairbank changes. On the other hand, it was not possible to demonstrate a correlation between osteoarthritis and complaints (Table 4).

DISCUSSION

Oretorp et al (1978) studying experimentally in dogs the immediate effect upon the knee of meniscectomy, reported that the removal of a

Table 3 Physical findings (n = 131)

	Per cent	Median score for complaints	
on in the knee	1.5	10	
ed mobility	6.1	7.5	
eral instability	13.7	6.5	
r sign	9.9	5	
ness on joint line	11.5	10	
iceps atrophy	8.4	7	
physical finding	61.8	0	} $P < 0.001$ (Spearman correlation test)
physical finding	26.7	4	
physical findings	9.9	10	
physical findings	1.5	13	

Table 4 Radiography

	Per cent	Median score for complaints	
Flattening of femoral condyle	51.9	4	
Marginal osteophytes	39.7	4	
Narrowing of joint space	21.4	2.5	
Number of Fairbank changes			
0	40.5	0	} $P < 0.001$ (Mann-Whitney)
1	17.6	3	
2	30.5	4	
3	11.5	4	
Osteoarthrosis	22.9	1.5	$P < 0.01$ (Mann-Whitney)
No osteoarthrosis	77.1	2	

meniscus resulted in increased laxity in the knee joint, indicating that the meniscus carried out a weight-bearing function. The laxity was greater after medial meniscectomy, presumably due to the anatomical relationship between the medial meniscus and the deep fibres of the medial collateral ligament.

Among the present meniscectomized athletes, 21 per cent complained of a sensation of instability, and at follow-up 14 per cent had collateral instability which must be interpreted as a sequelae to the meniscectomy as patients with ligament injuries observed at operation were excluded. Thus, the clinical findings support the hypothesis of the weight-bearing function of the meniscus. The increased instability may be a contributory cause of the high incidence of new knee injuries after meniscectomy. In the course of the follow-up period median 4 years 3 months 8 per cent sustained new knee injuries. This is a high incidence of injuries, even among athletes. Among 108 randomly selected men in the age range 30-40 representing the population of males of this age in Gothenburg, Sweden Roaas & Andersson (1977) found that 6 per cent had had meniscus injuries and 4 per cent ligament injuries at some time or other.

Previous authors have analysed the complaints after meniscectomy by grading

systems in which each symptom is given a score according to the degree of the individual patient (Appelby et al 1974, Tapper & Hoover 1974). The definitions of grading the symptoms have often been vague and the grades based upon an estimate. This is difficult for subsequent interobserver and intraobserver results. In the present study a system in which the symptoms are graded mutually *a priori* and the results could merely confirm or reject the hypothesis. The system has proved applicable and can be considered reproducible.

It was not possible to detect a relation between the length of the follow-up period and the complaints. This agrees with previous findings (Appelby et al 1974, Tapper & Hoover 1974). By 79 per cent it was stated that the complaints had been present since the injury. It is most likely that the complaints after meniscectomy are functional disturbances and not structural changes which would be expected to change with time. Indeed there was a correlation between complaints and radiographic arthrosis.

The complaints following meniscectomy made 27 per cent of the patients restrict their athletic activities. This

if patients in whom the athletic were influenced more than in other. In particular, the branch or level of it had no influence. Such a high y of altering activity stresses that the of a meniscus entails a radical n knee function, manifesting itself in um strain which occurs in perform- t. The design of the present study t permit conclusions as to whether it sable to continue athletic activities eniscectomy, but considering that 46 did not have complaints and that it possible to predict which groups of would develop complaints, it seems le to advise resuming sports after the rative restitution of the quadriceps

ix patients in the present material partial meniscectomy, and it is not to compare the results of partial and eniscectomy. A few previous nions have demonstrated good results tial meniscectomies (Strehl 1955, Hoover 1969), but a definite to the choice partial/total meniscec- must await the results of controlled studies.

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GENITAL POSTEROMEDIAL BOWING OF THE TIBIA

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Posteromedial bowing of the leg is a rare entity and only a few cases have been described in the literature. A report is made of six patients with this deformity. Except for one severe case requiring anterior soft tissue release, the deformity was corrected in all patients by repeated application of plaster casts. A conservative approach to the management of this condition is advocated.

Key words: congenital deformity, kyphoscoliotic tibia, posteromedial bowing tibia.

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and associates (1952) coined the term "genital kyphoscoliotic tibia" for congenital bowing of the tibia with anterolateral or posteromedial curvature. The posteromedial bowing is an entity which is more uncommon than the anterolateral one and only a few cases have been reported (Heyman & Herndon 1949, Heyman 1951, Rathgeb et al 1974). Frequently associated with a calcaneovalgus deformity of the medial foot and the dorsum of the foot may touch the lower third of the leg (Fig. 1). Roentgenologically there is a wedge-shaped area at the site of the deformity, which is marked on the concave side of the curve (Fig. 2).

In this presentation six cases of posteromedial bowing of the leg treated conservatively are reported.

PATIENTS AND METHODS

During the period 1974 to 1978 six patients with congenital kyphoscoliotic tibia were observed. Three patients were males and three females. Their

ages ranged from 22 days to 90 days. In all the cases the lesion was on the left side. The diagnosis was based upon clinical observations and radiological findings. Five cases had associated congenital clubfoot. No other congenital anomalies were observed.

Other five patients were managed conservatively with plaster casts applied at intervals of 4 weeks. A total of six to eight casts were sufficient to achieve an adequate correction of the deformity. The patient shown in Figures 1 and 2 demonstrated complete clinical and radiological correction of the deformity after a follow-up of 4 years (Figures 3 and 4).

DISCUSSION

In the medical literature there is an emphasis on the anterolateral type of kyphoscoliotic tibia due to its association with pseudoarthrosis and neurofibromatosis (Aegerter 1950, Badgley et al 1952, Gwim & Barnes, 1967, Hardinge 1972, Rathgeb et al 1974, Newell & Durbin 1976). Posteromedial bowing of the tibia is a benign condition



Figure 1 Congenital posteromedial bowing of the left leg showing the typical deformity



Figure 2 Roentgenogram of the lower leg - the fibula lies on in the lower one-third of the tibia



Figure 3 The same leg 3 years after correction of the deformity



Figure 4 Roentgenogram of the lower leg - complete correction of the deformity

responds adequately to plaster casting (Heyman et al 1959, Newell & 1976). As both sides are equally prone to deformity, it may be a coincidence that patients had left-sided pathology. Five cases were corrected by serial plaster and only one case with a severe deformity needed a prior anterior soft tissue release. None of these cases revealed signs of neurofibromatosis. The calcaneovalgus deformity of the foot was fully corrected but all show a moderate impairment in walking. The residual leg length discrepancy requires arrest of growth on the medial side (Krida 1951, Rathgeb et al 1974). Since all our patients are too young for osteotomy, arthrodesis is not considered appropriate at present.

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Figure 1 Congenital posteromedial bowing of the left leg showing the typical deformity



Figure 2 Roentgenogram of the lower end of the femur showing the lesion in the lower end of the femur



Figure 3 The same leg 4 years after correction of the deformity



Figure 4 Roentgenogram of the lower end of the femur showing complete correction of the lesion

GROWTH DISTURBANCE FOLLOWING FRACTURE OF THE TIBIA IN CHILDREN

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Orthoradiographs were produced from 13 to 36 months after tibial fractures in 85 children. Fifty-nine were complete i.e. transverse or longitudinal, and 28 fractures were incomplete i.e. infractions or fissures. The difference in the length of the tibia from growth disturbance caused by the fracture was found to be related to the age of the child at the time of fracture and the sex. An overgrowth was found to occur in the age group from 3 to 10 years in girls and from 3 to 12 years in boys, whereas in the older children a growth retardation was demonstrated. No correlation with the type of fracture, or with the residual angulation after reduction, could be established. The growth disturbance was found to affect 1 or 2 years. We conclude that a more concerned

Key words: children, growth disturbance, tibial fracture

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The induced disturbance of the diaphyseal growth rate of a long bone in children was first studied by Öller (for review see Guldhamner 1963, Öller 1969). The rather unconcerned attitude regarding the need for an exact knowledge of fractures of long bones in children, which had been widely accepted and challenged by Swaan & Oppers (1971) and others, in their 1976 study, showed that at a fracture site, a spontaneous correction of an angular deformation of more than 10% of the original deformity cannot be expected, irrespective of the child's age at the time of fracture. The aim of this study is to discuss the fracture induced disturbance of growth as it relates to age, sex, type of fracture, residual angulation after reduction and the duration of the disturbance in tibia and femur following a tibial fracture in children.

PATIENTS AND METHODS

This study included a total of 85 patients from 1-15 years of age with complete and incomplete

56 boys and 29 girls with 33 transverse fractures, 24 longitudinal fractures (classified according to Edwards 1965), 14 fissures and 14 infractions. The age distribution and sex ratio are given in Figure 1. All the patients were treated conservatively in a plaster cast. The time taken for union to be established was assumed to coincide with the time until removal of the cast which ranged from 2 to 18 weeks after the accident. By regression analysis it was demonstrated that the time required for union increased significantly with increasing age.

At 13 to 36 months (average 25.2 months) after the fracture all prior X-ray pictures were reviewed and any shortening at the time of union was estimated. Anteroposterior and lateral X-rays were taken of the tibia, and the angular deformity was measured as the angle between the axis of the

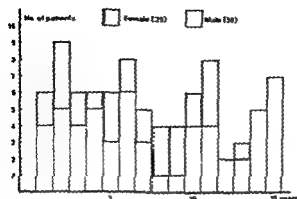


Figure 1 Age distribution and sex ratio

diaphyseal fragment proximally and distally to the fracture site, without regard to apposition and resorption at this level (Hansen et al 1976). The angular deformity was stated as the sum of the angulation in the anteroposterior and lateral views.

Spot-orthoradiography was performed to a reading accuracy of 1 mm. Spot-orthoradiography was accomplished in the following manner. The patient was placed supine on a large X-ray film with the legs stabilized by a couple of small sand bags. By focusing successively on the hip, knee and ankle joints separate exposures on the film were obtained of each joint. The distance between the X-ray tube and the object was about 1.5 m. Measurements on the film of the length of the tibia then indicated the real length of the bones. (Taillard 1956). Healing shortening, if any, was deducted from the measurements obtained from the spot-orthoradiographs.

F tests and t tests were employed for the statistical analysis.

RESULTS

The tibial growth-determined discrepancy induced by the fracture varied between -9 and +9 mm.

Age at the time of fracture

The growth-determined mean difference in tibial length in relation to age at the time of the accident is given in Figure 2. In the age group 1 to 2 years, the mean tibial difference was close to zero, whereas a growth stimulation (+4.2 mm) occurred in the age group 3 to 5 years. The difference between the two

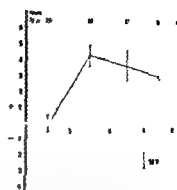


Figure 2 The mean growth-determined difference in tibial length in mm (corrected for the length of the tibia in mm) in relation to age at the time of fracture. SEM = standard error of the mean; N = numbers of patients in the group.

groups was statistically significant ($P < 0.001$). With increasing age, the stimulation appeared to decrease. For example, in the age group 12 to 15 years, overgrowth was found to be 1.0 mm. 15-year-olds (boys) showed a stimulation. The differences in the next three age groups 9 to 11 years, 12 to 14 years and 15 years were not significant ($P < 0.01$ and $P < 0.05$).

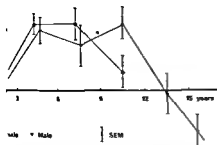
Sex

The growth-determined mean difference in tibial length in relation to age at the time of the accident is given in Table 1. No significant differences in the growth stimulation in relation to sex were found.

Table 1 The mean growth-determined difference in tibial length in mm (corrected for the length of the tibia in mm) in relation to age at the time of fracture.

Age in years	n	Female mean	Female SEM	Male mean	Male SEM
1-2	6	-1.65	1.07	0.0	0.0
3-5	6	4.50	0.71	12.0	1.4
6-8	7	4.47	1.13	17.0	1.4
9-11	9	1.33	1.10	4.0	1.2
12-14	7	-	-	-	-
15	0	-	-	-	-

SEM = standard error of the mean.
* indicates $P < 0.05$.



The mean growth induced difference in mm (ordinate) and SEM (standard error of the mean) correlated to the age of the boys ∇ at the time of fracture (abscissa) of 27 numbers of patients in the groups

and below the age of 9 years, but a significantly ($P < 0.05$) reduced overgrowth was found after fracture in girls aged 9 to 11 years (Figure 3).

fracture

At the age of 3 years, 86 per cent of the fractures were incomplete. A comparison of the tibial difference caused by the various types of fractures was made for children from 3 to 15 years of age. The correlation between the type of fractures and the growth stimulation is not statistically significant (Table 2).

Angulation at the time of union

The influence of angulation on the growth stimulation was studied in the children from the ages of 3 and 15 years. Even a small angulation appeared to induce an

Table 2 The mean growth induced difference in mm correlated to the type of fracture in children aged 3-8 years

Type of fracture	n	mean	SEM
Complete	8	4.37	1.23
Inverse	15	4.53	0.94
Proximal	12	3.00	0.74

SEM = standard error of the mean

Table 3 The mean growth induced difference in tibial length in mm correlated to angulation at the time of union in children aged 3-8 years

Angulation at time of union	n	mean	SEM
4-19 degrees	11	5.01	0.87
none	24	3.45	0.68

SEM = standard error of the mean

increased growth stimulation, the difference between the mean tibial difference in angulated and non-angulated fractures was not statistically significant (Table 3).

Duration of the growth disturbance

The patients were divided into two groups, those who had been observed for less than 2 years and those observed for more than 2 years. The distribution as regards age and sex of the two groups was comparable. No statistically significant difference between the growth-induced mean tibial difference in the two groups could be found (Table 4).

The femur

The mean growth-determined difference in femur length for the 57 patients with complete tibial fractures is shown in age groups in Figure 4. The pattern of growth stimulation/retardation seen in the tibia appears to be also valid for the growth-response in the femur.

Table 4 The mean growth induced difference in tibial length in mm correlated to the period of observation. The two groups are comparable (Fourfold Table), and five girls over the age of 9 years appear in each group

Period of observation	female	male	mean age	mean difference in tibial length
< 2 years	14	26	7.07	2.67 \pm 0.63
> 2 years	15	30	7.73	1.62 \pm 0.54

SEM = standard error of the mean

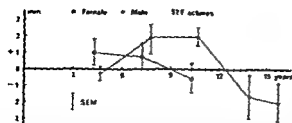


Figure 4 The mean growth induced difference in femur length in mm (ordinate) and SEM (standard error of the mean) correlated to the age of the boys Δ and girls \bullet at the time of tibial fracture (abscissa)

A statistically significant ($P < 0.05$) difference between the growth-response in girls and boys aged 9 to 11 years was found. The boys displayed a femur overgrowth of an average of 2 mm while the girls displayed a growth retardation of an average of 0.5 mm. A growth retardation of the femur averaging 2 mm occurred in boys above the age of twelve.

DISCUSSION

The clinical measurement of anisomelia by correcting the pelvic tilt with wooden blocks placed under the shorter limb or by employing a measuring tape show a tendency towards underestimation (Edwardsen & Sørensen 1976, Swan & Oppers 1971). Assuming a minimal error of focusing at the performance of spot-orthoradiography the measurement on the film will indicate the correct total length of the bone with an accuracy of $\frac{1}{2}$ –1 mm (Taillard 1956) and the error of the difference would be so minimal that it could be ignored. The physiological anisomelia was clinically assessed by Barfoed & Christensen (1959) in 431 children. They found isomelia in more than 90 per cent of the children, while Guldhammer's (1963) study of skeletons showed that total isomelia is probably the exception, but the difference in the majority of the population is less than 2 mm. As no spot-orthoradiography was performed prior to the accident the physiological anisomelia could not be corrected for in this study and as the magnitude of the physiological variation

appears to be less than the traumatic anisomelia this source of error will be of minor importance for the results of this study.

The fracture-induced growth retardation in anisomelia found in the present study instance reached a clinically significant level requiring correction. An average leg-length discrepancy of 2 cm is of minor importance in adults. The fracture-induced growth retardation depends on the child's sex and age at the time of the accident, as shown by Swan & Oppers (1971), was confirmed by this study and supported by an analysis of the literature presented by Guldhammer (1963).

The correlation of growth retardation at the time of the accident is determined by the different amount of immobilization required for union and the degree of immobilization. Muscle contracture and blockage of the efferent venous system are one of the most important factors in the diffusion of oxygenated blood into the sinusoid of the bone marrow (Hägg & Trueta 1965). Bone immobilization after fracture healing then probably causes a depressed bone growth rate. This is supported by an increased growth rate lasting more than 2 years (Swan & Oppers 1971, Guldhammer 1963), due to the increased blood circulation, which follows a fracture (Kellermans et al. 1970) or increased accretion (Wendeborg 1961).

In very young children the growth period is very short and the growth retardation is consequently minimal. Growth is rapidly restored and overgrowth is established. In children aged from the prepuberty to the puberty period the growth is substantial and the growth retardation is maximal, which allows the growth to speed up in the period of the fracture. The increased blood circulation and the increased blood circulation at the fracture site in the prepuberty normally display a growth retardation. They appear unable to react to the growth retardation in the younger children, and the growth retardation experienced during the fracture

the fracture cannot be corrected
ously

reason for the different growth
in the two sexes might be related to
biological difference in bone maturity
same chronological age as it is well
that the girls cease growing earlier
boys

type of fracture and the angulation at
the site of union is apparently of no im-
portance for the growth response following a

A necessary condition for such cor-
rection to exist would be a different healing
of different types of fractures which is
not the case (Hansen et al 1976) and a
relation in the secondary hyperaemia
following a fracture a correlation which has
not been established either

growth disturbance of the ipsilateral
increased the anisomelia produced by
the growth response of the fractured tibia
indicates that the hyperaemia is by no
means a local event in the tibia but includes
the whole extremity. However this does not
agree with the findings of Guldhammer
who stated that growth stimulation
does not occur in bones other than the
fractured one

It is generally accepted that an anisomelia
of 2 cm in adults is of no importance
(Jensen 1956). Guldhammer (1963)
has concluded that a shortening of a tibia fracture
to 1 cm with an otherwise correct
union does not indicate the need for an os-
teostomy in a child with a few years of
growth remaining. This statement has led to
confusion as to whether an anatomical
union of a fractured tibia in a child is
sufficient. The magnitude of the overgrowth
in children under the age of 9 years was
approximately 0.5 cm. Fear of such a residual
anisomelia should not prevent the
achievement of an exact reduction. From the
experience of 10 years in girls and 12 years in boys
our study shows that no overgrowth can be
predicted. On the contrary, the spot
orthoradiography demonstrated a growth
stimulation in the tibia as well as in the
femur which together may lead to an

anisomelia of close to 2 cm. A more
concerned attitude towards residual shorten-
ing at the time of reduction in tibia fractures,
at least in these older children, has therefore
to be adopted, in order to ensure a final
anisomelia of less than 2 cm.

In future studies it is recommended that an
assessment of the bone maturity is made at
the time of fracture and at the same time a
spot-orthoradiography is performed and
repeated 1 and 2 years after the accident.

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ARTROGRAPHY AS A GUIDE IN THE TREATMENT OF CONGENITAL CLUBFOOT

Incidence and Treatment Results in a Consecutive Series

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Simultaneous arthrography of the talocrural and talonavicular joints performed on 32 out of a consecutive series of 48 congenital clubfeet revealed a talar dysplasia that varied considerably both in type and degree.

This great variability meant that no simple and practically useful classification could be made on the basis of arthrographic findings. It in-

stead, the results of the operations varied from lengthening of the tendo Achillis to extensive soft-tissue procedures, in some cases combined with correction osteotomy through the neck of the talus and the calcaneus. The results were relatively good, but the investigation showed that in many cases the talar dysplasia places a definite limit on the achievable result.

Arthrography is not indicated in easily corrigible cases. This examination should always be carried out, however, in clubfeet that are difficult to correct or are recurrent before making a decision about surgical treatment. In these cases the arthrographic findings can be used as a guide in the choice of therapeutic method. The talar dysplasia seems not to alter appreciably during the first year of life and it would therefore seem

Key words: ankle joint, clubfoot, radiography, talus, therapy.

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gave a good description of the skeletal anomalies in clubfoot as early as in 1822. Like many more recent authors (e.g. Sherman 1963, Settle 1963, Reimann 1963, Hjelmstedt & Sahlstedt 1974), he found individual variations in both the degree and type of dysplasia. Attempts have been made previously (Bertrand 1947, Poulain 1952, Cabanac *et al.* 1952) to examine the deformity in clinical cases by arthrography of the ankle joint and some

flattening of the trochlear curvature has been observed. Settle (1963) realized the value of simultaneous arthrography of the talocrural and talonavicular joints, but did not succeed in this except during surgery.

Since 1970, however, after a series of investigations on autopsy foot specimens, we have found it possible to carry out simultaneous arthrography of these two joints in clinical practice. The method involves well-defined standard roentgenological projections,

measurement and analysis of different variables, a carefully worked out joint-puncture technique and a standardized pressure of injection (Hjelmstedt & Sahlstedt 1973, 1974, 1978, Hjelmstedt 1974a,b, Sahlstedt 1974)

Such simultaneous arthrography has been performed routinely on refractory and recurrent clubfeet, and side by side with the findings at clinical examination has served as a guide for future treatment (Hjelmstedt & Sahlstedt 1973, Hjelmstedt 1974a,b, Sahlstedt 1974, Hjelmstedt & Sahlstedt 1978)

In this article the arthrographic findings in a consecutive series of clubfeet are presented. In addition, the value of arthrography in the choice of treatment is demonstrated and the correlation between the findings at arthrography and the therapeutic results is reported.

PATIENTS AND METHODS

The material consisted of 48 idiopathic clubfeet in 30 patients who were followed up for a mean period of 6.3 years (range 3.5–9 years). There were 8 girls and 22 boys. The series comprised all children with clubfoot who were born and primarily treated in the county of Uppsala between January 1969 and July 1974.

In all cases the primary treatment was manual manipulation and serial casts and was started on one of the first days after birth.

Twenty feet were corrected successfully by conservative treatment alone, while the other 28 had later to undergo operation on account of unsatisfactory correction or recurrent deformity.

The operation cases have been divided into two groups in Table 1 according to whether corrective osteotomy through the talus and calcaneus was performed or not. The operative measures are presented in detail in this Table, from which it is seen that the soft tissue procedures were individualized, but that lengthening of the tendo Achillis and the tendon of the posterior tibial muscle was performed in the majority of cases.

The indication for operation was unsatisfactory correction or recurrence of the deformity.

Soft tissue operations without talo-calcaneal osteotomy were performed in cases where pre-operative arthrography showed:

(a) that the dislocation of the navicular bone was relatively slight (Figure 1) or

(b) that the dislocation of the talus was relatively pronounced, but that the prerequisites for open reduction were present.

By open reduction of the talus the intended reduction of the bone is achieved after division of the capsule and the talonavicular joint medially and laterally.

Soft tissue procedures and osteotomy were undertaken in cases where pre-operative arthrography showed:

(a) pronounced medio-lateral dislocation of the neck and head of the talus or

(b) total or subtotal obliteration of the talonavicular joint space. It was considered that reduction of the talus to its normal position would be achieved (Figures 3 and 4).

Operative procedures

Lengthening of tendons was carried out by a Z-plasty. Only in a few cases lengthening of the tendo Achillis earned the designation of Z-plasty. The most common of the measures which were performed was lengthening of both the tendons of the posterior tibial muscle tendon. The incision between the tibia and the

In the most extensive soft tissue procedure a Z-plasty was made from the medial aspect and carried proximally behind the malleolus. The tendo Achillis, the posterior tibial muscle and the long flexor tendons of the metatarsals were cut with a Z-plasty. The plantar fascia was divided in the tuberosity of the abductor hallucis muscle and the insertion on the tuberosity and the medial aspect of the foot by careful dissection. Damage to blood vessels and nerves was avoided. The part of the divided posterior tibial tendon was then drawn down through the incision. The talonavicular ligament and the talonavicular joint medially and laterally and the capsule had also been divided. In this aspect the navicular bone was in its normal position. The divided posterior tibial muscle tendon was then drawn down through its tendon sheath and the desired amount of lengthening was achieved. The other divided tendons of the peroneal tendons were drawn down through an incision distal to the malleolus. In some cases the anterior tibial muscle was transferred from the second or third metatarsal

Table 1 Details of the operative treatment. The material is divided into two groups (1) operative treatment without talo-calcaneal osteotomy and (2) operative treatment including talo-calcaneal osteotomy. It is seen that the soft tissue procedures varied greatly from case to case but that lengthening of the tendo Achillis and the posterior tibial muscle tendon was performed on most of the clubfeet. By open reduction of the navicular is meant here reduction after division of the capsule and ligaments of the talonavicular joint medially and on the plantar aspect. The operative treatment was sometimes carried out in two sessions with an interval of 6-18 months.

Treatment	Lengthening of				Shorten- ing of	Transfer of ante- rior tibial muscle tendon	Release of abd hall muscle + planto- tomy	Open reduction of the navicular bone	Wedge osteotomy through	
	Tendo Achillis	Post tibial tendon	Flex dig long tendon	Flex hall long tendon	one or both peroneal tendons				Cuboid	Talar neck + calcaneus
Conservative + soft tissue procedures (+ wedge osteotomy in the cuboid, 3 feet) N = 23	20	17	1	1	5	11	8	9	3	-
Conservative + soft tissue procedures + talo-calcaneal osteotomy N = 5	5	5	-	-	2	-	3	-	-	5
Total = 28	25	22	1	1	7	11	11	9	3	5



Figure 1 Clubfoot deformity in a 2 year old girl. Simultaneous arthrography of both talonavicular joints. Spontaneous contrast filling of a medial tendon sheath occurred.

a Lateral view. The ankle recesses are small. The plantar deviation of the talonavicular joint is increased ($\beta = 38^\circ$).

b Dorsoplantar view. The medial deviation of the talonavicular joint is increased ($\alpha = 12^\circ$). The head has a normal rounded form.

Operation. Lengthening of the tendo Achillis and the posterior tibial muscle tendons.

Result. Excellent.

procedure but as a rule this was done at a later session.

Corrective osteotomies (Hjelmstedt & Sahlstedt to be published in Acta orthop. scand.) through the neck of the talus and the calcaneus was performed through an incision over the tarsal sinus, with removal of a wedge of bone through the talar neck as shown in Figure 5. The osteotomy through the calcaneus is done at the same level as in the talus and one has to test one's way forward to see how large a wedge needs to be removed from the calcaneus. The osteotomies were always combined with simultaneous soft tissue operations performed through a medial

incision. The talonavicular joint was opened as the vascular supply of the talus after osteotomy of the talonavicular joint capsule.

Suction drainage was applied to the cutaneous tissue and skin was closed with a single rather close suture. The foot was observed after full anaesthesia and considered unsatisfactory the correction seemed somewhat before the plaster was applied. The cast was changed after anaesthesia with 70 mg and the foot fixed in a naturally corrected position. The foot was kept in the cast for 2 weeks.



Congenital clubfoot in a 14-year-old boy. Simultaneous arthrography of the ankle and talonavicular joints. Spontaneous contrast filling of a medial tendon sheath occurred in the ankle view. The ankle recesses are slightly reduced in size. There is slight flattening of the trochlea ($\beta = 0.43$). Normal plantar deviation of the talonavicular joint is seen ($\beta = 26^\circ$). In the plantar view, the medial deviation of the talonavicular joint is increased ($\beta = 47^\circ$) and the talus bone is displaced medially. The talar head, however, has preserved its normal form. Lengthening of the tendo Achillis and posterior tibial muscle tendon + release of the plantar flexor of the abductor hallucis muscle from the calcaneus + open reduction of the navicular tendon. Result: very good.

weeks. The cast covered the whole leg and was in 90° flexion. No complicating skin sores occurred and no vascular necrosis in the head of the talus was noted in this material.

phy

Simultaneous arthrography of the talocrural and talonavicular joints was carried out on 32 of the feet. Fourteen feet were corrected relatively by conservative treatment and in these there was no indication for arthrography. In the other 18 feet, the arthrography was unsuccessful and 14 of these feet for which surgical treatment was necessary, preoperative arthrography

was performed and the information thus obtained was used as a guidance in drawing up a suitable plan of treatment.

The arthrographs were performed as described by Sahlstedt (1976). The reliability of the method of radiographic measurements used has been investigated previously and found to be reliable for the variables reported here.

L = length of talus
R = radius of the trochlear curvature
R/L = index of the flattening of the trochlea



Figure 3 Congenital clubfoot in a 3-year old boy. Simultaneous arthrography
 a Lateral view. The ankle recesses are small (Flattening index $R/L = 0.4^\circ$) and the flattening of the talar neck and of the talonavicular joint is observed ($\beta = 51^\circ$)
 b Dorsoplantar view. There is pronounced medial deviation of the neck and head of the talonavicular joint ($\gamma = 66^\circ$). The talar head is deformed and the recesses of the talonavicular joint are partially obliterated.

Operation. In two sessions the following were performed: lengthening of the tibia, tibial tendon correction, osteotomy through the talus and the calcaneus and transfer of the tibial tendon.

Result. Good.

- α central angle of the trochlear curvature
- β plantar deviation of the talonavicular joint
- γ medial deviation of the talonavicular joint

An analysis of measurement values from a material of clubfeet has been published previously (Hjelmstedt & Sahlstedt 1978). In this it was found that a reduction of the central angle of the trochlear curvature (α) was correlated to an increase of the flattening of the trochlea (index R/L). Further a weak correlation was found between a decreased α and an increased medial deviation of the talonavicular joint (γ). This was the only correlation between the changes in the

ankle joint and those in the tarsus. This means that it is not possible to make a practically useful classification of the deformity on the basis of arthrography. Thus, the most striking radiological deformity is the marked plantar deviation of the axis. In one case a marked medial deviation of the axis and marked flattening of the trochlea were seen. In another case a very small central angle of the trochlea was seen. Thus variability is considerable and it is not evident from the average values presented here.

The mean values obtained



Severe clubfoot deformity in a 1½ year-old boy. Simultaneous arthrography. Spontaneous filling of a medial tendon sheath occurred. Anteroposterior view. There is obvious flattening of the trochlea ($R/L = 0.46$) and subtotal obliteration of the recesses. Marked plantar deviation of the neck of the talus and of the talonavicular joint ($\beta = 44^\circ$). Lateral view. The talonavicular joint shows marked medial deviation ($\gamma = 59^\circ$) and its recesses obliterated. Operative treatment. Lengthening of the tendo Achillis and the posterior tibial muscle tendon + release of the fascia and the abductor hallucis muscle from the calcaneus + correction osteotomy through the distal end of the calcaneus. Good. The reduced mobility of the ankle is partly compensated for by hypermobility in the subtalar joints.

aims for different treatment groups and for the material are presented in Table 2. For comparison normal values are also given. Of the 10 feet that were only treated conservatively, arthrography was only performed on the six that were most difficult to correct and the data given therefore not representative for the whole group. As seen in the Table the mean values for the six feet showed considerable discrepancy from normal values with respect to the central angle (α) and the index of the flattening of the talus. While for plantar deviation (β) there was

no discrepancy and for medial deviation (γ) the difference was only slight. The mean values for the surgically treated feet, on the other hand, all differed considerably from the normal values.

RESULTS OF TREATMENT

The evaluation of these results was based upon clinical examination at the age of 3.5–9 years (mean age 6.3 years). The criteria for



Figure 3 Congenital clubfoot in a 3 year-old boy. Simultaneous arthrography
a Lateral view. The ankle recesses are small. (Flattening index $R/L=0.42$) Marked flattening of the talar neck and of the talonavicular joint is observed ($\beta=51^\circ$)
b Dorsoplantar view. There is pronounced medial deviation of the neck and head of the talus the talonavicular joint ($\gamma=66^\circ$). The talar head is deformed and the recesses of the talonavicular joint are partially obliterated.

Operation. In two sessions the following were performed: lengthening of the tendo Achillis and tibial tendon, correction osteotomy through the talus and the calcaneus, and transfer of the tibial tendon.

Result Good

- α = central angle of the trochlear curvature
 β = plantar deviation of the talonavicular joint
 γ = medial deviation of the talonavicular joint

An analysis of measurement values from a material of clubfeet has been published previously (Hjelmstedt & Sahlstedt 1978). In this it was found that a reduction of the central angle of the trochlear curvature (α) was correlated to an increase of the flattening of the trochlea (index R/L). Further, a weak correlation was found between a decreased α and an increased medial deviation of the talonavicular joint (γ). This was the only correlation between the changes in the

ankle joint and those in the talonavicular joint. This means that it is not possible to use a practically useful classification of the deformity on the basis of arthrography. Thus, the most striking talar deformities are: marked plantar deviation of the talonavicular joint in one case, a marked medial deviation of the talonavicular joint in a second case, and marked flattening of the trochlea in a third case.

This variability is important to keep in mind. It is not evident from the arthrographic values presented here.

The mean values obtained from



Severe clubfoot deformity



Arthrography Spontaneous

0.46) and subtotal obliteration of the

Marked plantar deviation of the neck of the talus and of the talonavicular joint is

$\beta = 44^\circ$) The talonavicular joint shows marked medial deviation ($\gamma \sim 59^\circ$) and its recesses

obliterated. Lengthening of the tendo Achillis and the posterior tibial muscle tendon + release of the fascia and the abductor hallucis muscle from the calcaneus + correction osteotomy through the distal calcaneus

Good The reduced mobility of the ankle is partly compensated for by hypermobility in the talonavicular joints

Results for different treatment groups and for the material are presented in Table 2. For comparison normal values are also given. Of the feet that were only treated conservatively arthrography was only performed on the six that were most difficult to correct and the data given therefore not representative for the whole group. As seen in the Table the mean values for the six feet showed considerable discrepancy from the normal values with respect to the central angle (α) and the index of the flattening of the foot (β) while for plantar deviation (β) there was

no discrepancy and for medial deviation (γ) the difference was only slight. The mean values for the surgically treated feet on the other hand all differed considerably from the normal values.

RESULTS OF TREATMENT

The evaluation of these results was based upon clinical examination at the age of 3.5-9 years (mean age 6.3 years). The criteria for

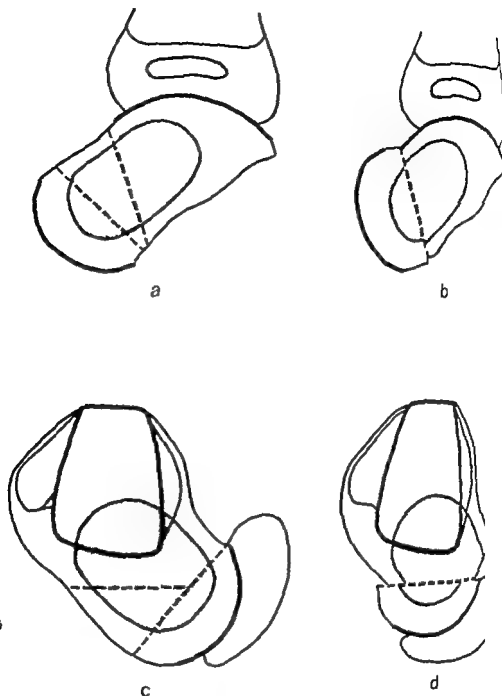


Figure 5 Schematic drawing of osteotomy through the talar neck.

- a Lateral view of a clubfoot talus. Note the flattening of the trochlea and plantar process and head. The osteotomy lines are marked with short dashes. The base of the wedge is on the dorso-lateral side of the neck.
- b Correction after wedge osteotomy. The actual shortening of the talus will be about 10% of its former length.
- c A clubfoot talus and the navicular bone seen from above. The joint borders are marked with solid lines and the osteotomy lines with short dashes. Note the pronounced medial deviation of the neck and head and the obliteration of the original talonavicular joint.
- d Correction after osteotomy.

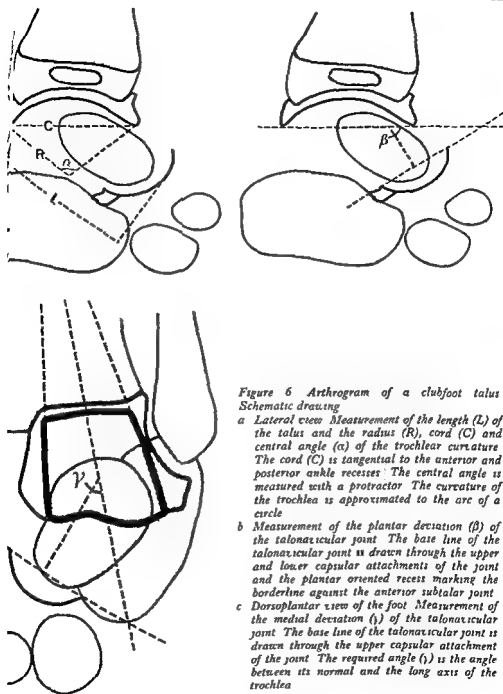


Figure 6 Arthrogram of a clubfoot talus
Schematic drawing

- a Lateral view Measurement of the length (L) of the talus and the radius (R), cord (C) and central angle (α) of the trochlear curvature. The cord (C) is tangential to the anterior and posterior ankle recesses. The central angle is measured with a protractor. The curvature of the trochlea is approximated to the arc of a circle.
- b Measurement of the plantar deviation (β) of the talonavicular joint. The base line of the talonavicular joint is drawn through the upper and lower capsular attachments of the joint and the plantar oriented recess marking the borderline against the anterior subtalar joint.
- c Dorsoplantar view of the foot. Measurement of the medial deviation (γ) of the talonavicular joint. The base line of the talonavicular joint is drawn through the upper capsular attachment of the joint. The required angle (γ) is the angle between its normal and the long axis of the trochlea.

tion of the results are given in Table 4. In borderline cases it was chosen to assign them to the poorer group. In Table 4 the results are presented in relation to different types of treatment, and in

Table 6 in relation to demonstrated talar deformity.

For 20 of the 48 feet an excellent or very good result was achieved with conservative treatment alone.

Table 2 The arthrographic variables in the clubfoot material and in a previously published material (Hjelmstedt & Sahlstedt 1977). The methods of measurement of the different variables are shown in Figure 6. For the clubfeet mean values and ranges are given and for the previously published material mean values and tolerance limits. $n=6/20$, and so on, means that 6 out of 20 feet were examined arthrographically. 14 of the 16 feet not submitted to arthrography were corrected after a longer period of conservative treatment. It is reasonable to assume that the dysplasia in these cases is more pronounced than in those examined arthrographically. In two cases arthrography was technically unsuccessful. R =radius of the trochlear curvature and L =length of talus.

Type of treatment

Variable	Conservative treatment only $n=6/20$	Conservative treatment + soft tissue procedures $n=21/23$	Soft tissue procedures + talo-calcaneal osteotomy $n=5/5$	Total $n=32/49$	Range
R/L =index of "the flattening of the trochlea"	0.43 0.39-0.48	0.42 0.38-0.49	0.44 0.40-0.49	0.42 0.38-0.49	0.35-0.5
Central angle α of the trochlear curvature	127° 109-138°	123° 101-150°	129° 110-143°	125° 101-140	100-150°
Plantar deviation β of the talonavicular joint	24° 15-34°	36° 20-49°	43° 36-53°	35° 15-53°	10-60°
Medial deviation γ of the talonavicular joint	23° 12-35°	38° 18-60°	42° 18-58°	35° 12-60	10-60°

Table 3 Classification of the treatment results based on the findings at clinical examination and arthrography in 32 of the 48 feet. The degrees of dysplasia of the talus and calcaneus are given in Table 6, a correlation was found between the degree of talar deformity and the treatment result.

	Excellent	Very good	Good	Fair
Dorsal extension of the foot	$\geq 15^\circ$	10-15°	5-10°	0-5°
Plantar flexion of the foot	$\geq 25^\circ$	$\geq 20^\circ$	$\geq 15^\circ$	$\geq 10^\circ$
Mobility of subtalar joints	normal	good	possibly slightly reduced	reduced
Mobility of midtarsal joints	normal	good, possibly hypermobile	good, possibly hypermobile	possibly reduced
Deformity on weight-bearing				
equinus	-	-	-	-
varus	-	-	-	$\geq 1^\circ$
adductus	-	negligible	$< 15^\circ$	negligible
Gait without shoes	normal	good	good	good
with shoes	normal	good	good	good

The results in the 23 feet that underwent soft tissue procedures without talo-calcaneal osteotomy varied considerably. For 17 feet they were evaluated as excellent-good, whereas in 6 cases they were only fair. In the latter cases the dorsiflexion in particular, was

only very slight, and one case showed a contracture of the anterior tibial muscle.

The result was evaluated as excellent-good for the five feet submitted to talo-calcaneal operations in combination with talo-

Results of treatment after an observation time of 3.5-9 years (median 6.3 years) in the series of 48 idiopathic clubfeet in 30 patients born 1/1/1969-31/7/1973. The criteria for selection of the results are given in Table 3. Arthrography was performed preoperatively in 26 of the 28 surgically treated feet and in 6 of the 20 feet treated conservatively.

Treatment	Results				
	Excellent	Very good	Good	Fair	Total
treatment only	16	4	—	—	20
treatment + soft tissue procedures	2	9	6	6	23
osteotomy on the cuboid in	—	3	2	—	5
treatment + soft tissue procedures	18	16	8	—	48
cuboid osteotomy					

Comparison between the findings at arthrography performed early and at later ages. More dysplasia might have been expected with increasing age, but this was not the case within the age of life. In the small group of children not examined until the age of 2-4 years, on the other hand, dysplasia was more marked. These were early cases in the series, and at that time we had experience of these arthrographs and the therapeutic principles based upon them. In many cases a cuboid osteotomy was done before planned osteotomy. In no case was arthrography performed at an age of 13-24 months.

Findings at the arthrography		Mean values for the arthrographic variables			
		R/L = index of the flattening of the trochlea	Central angle α of the trochlear curvature	Plantar deviation β of the talo-navicular joint	Medial deviation γ of the talo-navicular joint
conservative	n = 12	0.43	126°	31°	33°
surgical	n = 14	0.42	128°	36°	33°
late	n = 6	0.43	115°	37°	47°
values from material	n = 54	0.35	154°	24°	15°

Comparison between the findings at arthrography performed early and at later ages. More dysplasia might have been expected with increasing age, but this was not the case within the age of life. In the small group of children not examined until the age of 2-4 years, on the other hand, dysplasia was more marked. These were early cases in the series, and at that time we had experience of these arthrographs and the therapeutic principles based upon them. In many cases a cuboid osteotomy was done before planned osteotomy. In no case was arthrography performed at an age of 13-24 months.

Findings at the arthrography		Mean preoperative values of arthrographic variables			
		R/L = index of the flattening of the trochlea	Central angle α of the trochlear curvature	Plantar deviation β of the talo-navicular joint	Medial deviation γ of the talo-navicular joint
conservative	n = 5/18	0.41	131°	29°	30°
good and bad	n = 17/19	0.42	125°	32°	33°
late	n = 5/6	0.42	113°	42°	44°
values	n = 54	0.35	154°	24°	15°

To elucidate the question of whether the skeletal deformity alters with time, the mean arthrographic values are listed in relation to the different age groups in Table 5. It is seen that there was no appreciable difference in these values between feet examined within 2 months of birth and those examined at an age of 3–12 months. On the other hand, the values for the small group in which arthrography was not performed until the age of 2–4 years differed considerably from the others. The cases in the latter age group belong to the first in our series, and the reason for the greater degree of dysplasia might be that arthrography and the initiation of adequate surgical treatment was delayed too long. At that time the analysis and the indications for different forms of treatment had not yet been fully worked out.

The relation between the findings at the first arthrography and the results of treatment is shown in Table 6. The dysplasia was more pronounced in the group with fair results than in those with better results. The arthrographic values for the group with excellent results cannot be regarded as representative for the group as a whole, as only 5 of 18 feet were examined. The feet not subjected to arthrography may be assumed to have had a lower grade of joint dysplasia than those that underwent this examination.

The feet in which talo-calcaneal osteotomy was performed are not included in the Table, as the plantar and medial deviation (β and γ) would have been altered by this operation.

DISCUSSION

Anatomic studies have shown that deformation of the bones of the foot, especially the talus, is common in clubfoot (Adams 1851–52, Irani & Sherman 1963, Settle 1963, Reumann 1967, Sahlstedt 1974). It has been found in such studies that the dysplasia has varied considerably both in degree and type. With the arthrographic method used on the present material it has been possible to study

the talar deformity in a series of cases. In a previously published work (Hjelmstedt & Sahlstedt 1974) it was concluded that owing to the variability mentioned it is not possible to make any simple classification of clubfeet on the basis of arthrographic findings. From observations two conclusions have been

1. The variation of the talar deformity indicates that the deformity varies from case to case both in magnitude and in direction. This must be taken into consideration when planning the treatment, which therefore has to be individual.
2. Arthrography should be performed in cases that cannot be corrected quickly by conservative treatment, in order to determine the degree of joint dysplasia. This should be done before every kind of surgical intervention, even before achillotomy. It may be noted that of 28 feet in the present series 11 talus can already be considered as dysplastic and that the equinus position is associated with marked plantar deviation of the foot and neck of the talus. In such cases correction is gained by achillotomy but power is lost.

The method of simultaneous arthrography of the talocrural and talonavicular joints was developed in the hope of obtaining information that could be of value in the choice of treatment. This hope has in fact been disappointed and certain essential questions answered by this examination. As mentioned above, the matter of whether or not the Achilles should be lengthened can be decided after arthrographic analysis. The answer to the question to what extent in which direction the navicular is dislocated and of whether prerequisites exist for reduction of the dislocation or if a corrective osteotomy is the only satisfactory method.

Arthrographic analysis also allows insight into the best result that can be expected to be reached by treatment. For example, the examination reveals the flattening of the trochlea and

of the central angle of the trochlear (Figure 4), normal mobility can be hoped for with any form of treatment, but seldom completely, and even to some extent, but seldom completely, even for the restricted ankle

start of this investigation lack of experience made us somewhat uncertain about the rotation of the arthrograms and we had insufficient experience of corrective operations through the talar neck and

This gave rise to some hesitation about correct treatment in the first surgically investigated cases, which might have affected the results un-

it is impossible to say whether our results are better or poorer than those in other series, and the classifications into groups and the results may vary from one investigation to another. Moreover, our material is relatively

clear, on the other hand, that the treatment was based on better knowledge of the bony conditions than has been obtained previously. In our opinion arthrography is invaluable in the choice of treatment.

In the comparison of the arthrographic findings in different age groups (Table 5) it seems that some delay in initiating extensive forms of surgical intervention might result in an increase of the deform-

outline for examination and treatment has been developed as briefly as follows:

Initially all cases are treated by manipulation and serial casts, with a change of the plaster cast every week. The treatment is continued until maximal correction is preferably overcorrection, is achieved. A splint is then applied instead. A satisfactory result has been attained in 2-3 months, arthrography is unnecessary.

If a satisfactory result is not achieved or if the deformity recurs, arthrography is

always performed. On the basis of the arthrographic findings and observations at clinical examination it is then decided whether an operation is necessary to obtain the best possible correction, and if so, what soft-tissue and possibly skeletal procedure is indicated. Arthrography can be done as early as at 2 months of age, but is easier to perform and gives better films at an age of 6-12 months.

- 4 In exceptional cases lengthening of the tendo Achillis and possibly also of the posterior tibial muscle tendon can be done at an age of 2-3 months. As a rule, however, both minor and more extensive soft tissue operations, as well as osteotomies, should not, for practical reasons, be carried out before an age of 6 months and preferably not until 8-9 months. It is often suitable to perform the operations in two sessions. Talo-calcaneal osteotomy and lengthening of the tendo Achillis should not be carried out simultaneously, and transfer of the anterior tibial muscle tendon should not be done until maximal dorsiflexion of the ankle joint has been attained.

In view of the desirability of performing arthrography in refractory or recurrent clubfeet, and of the frequently rather extensive operations that are indicated the treatment of these cases should be centralized as far as possible.

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CALCANEAL OSTEOTOMY AND SOFT TISSUE PROCEDURES IN THE TREATMENT OF CLUBFEET

Indications, Principles and Technique

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By simultaneous arthrography of the talocrural and talonavicular joints it is possible to demonstrate and measure the most important skeletal deformities in clubfoot. In this way it has been possible to establish the indications for alternative forms of treatment with a greater degree of precision.

Most of our refractory or recurrent clubfeet have been treated successfully by various soft tissue procedures. In cases with severe talar deformity, however, these procedures have been complemented by correction osteotomy through the talar neck and calcaneus.

The aim is to create muscle balance by soft tissue procedures and to correct pronounced skeletal deformities by osteotomy. This treatment plan has been used in about 50 of our clubfoot cases. The principles, objectives and indications of the surgical therapy are discussed in this article.

The operative technique, as it has been developed with increasing experience, is described, and if careful attention is paid to all details the risk of complications is small and the correction is generally satisfactory.

It must be emphasized that correction osteotomy is only a part of an overall treatment plan and that this operation is only indicated in a minority of clubfoot cases.

Key words: arthrography, clubfoot, osteotomy, soft tissue procedures

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correction of the talar deformity in clubfoot by curettage of the ossification (die Entkernung des Talus) was described by Meusel as early as in 1890. A large material of clubfeet submitted to the "decancellation" of the talus, talar neck and cuboid was reported on by Muro in 1934. In 1932 Bradford described three cases that were corrected by osteotomy through the talar neck and calcaneus. Batchelor (1946) and Soga (1955) only performed osteotomy through the neck of the talus, whereas

Fredenhagen (1955) also removed a wedge of bone from the cuboid and inserted this into the osteotomy defect in the talus. Various soft tissue operations have often preceded or been performed in connection with the osteotomies.

The indications for these bone operations have previously been based mainly on the clinical findings, as conventional radiography of the feet in small children yields very little information as to the shape of the bones or the anatomy of the joints.

The introduction of simultaneous

arthrography of the talocrural and talonavicular joints has made it possible, however, to demonstrate the most important skeletal deformities in clubfoot and to measure them with a relatively high degree of accuracy (Sahlstedt 1976, Hjelmstedt & Sahlstedt 1974b, 1977, 1978a). This has enabled the indications for alternative forms of treatment to be established with greater precision. The arthrographies have shown that the skeletal deformity in refractory clubfeet is often so pronounced that good correction cannot be achieved by conservative treatment. Most of them, however, can be corrected by soft tissue procedures of varying extent, but in a minority of cases where operations must be complemented by wedge osteotomy through the neck of the talus and the calcaneus (Hjelmstedt & Sahlstedt 1979).

Since 1972 we have treated about 50 clubfeet by this form of correction osteotomy. In this article the indications for operation and the technique, as they have developed with increasing experience of the method, will be described.

THE PRINCIPLES AND AIMS OF THE SURGICAL TREATMENT

The principles are as follows:

- to correct the medial and plantar deviation of the neck and head of the talus by wedge osteotomy through the talar neck
- to correct the curvature deformity of the calcaneus and achieve the desired shortening by a slightly less angled wedge osteotomy through the calcaneus
- to correct any residual supination deformity by pronation of the foot distal to the osteotomies
- to facilitate the correction by division of the plantar aponeurosis and the tibionavicular ligament
- to normalize the muscle balance, thereby preventing recurrence, by a series of individually suited soft tissue procedures.

The soft tissue procedures used are: lengthening of tendons, release of abductor hallucis muscle, shortening peroneal tendons and transfer of the tibial tendon. Capsulotomy is not part of the treatment plan and is absolutely indicated in regards the talocrural because of the risk of necrosis of the head.

The aim of the treatment is to achieve the best possible function and fortunately is not always normal function. For example, in a talocrural deformity there is no possibility of achieving normal mobility in the hypermobility of the ankle joint to compensate for this to some extent and a fair result will then often be obtained if the function is not completely normal. By arthrography it is generally possible to judge in advance what function is attained.

INDICATIONS FOR OSTEOTOMY

The primary treatment of clubfoot is always be conservative. Operation is only be considered if the conservative measures have not resulted in adequate correction or if the deformity has recurred.

Before a decision is made about the extent of surgical treatment - including lengthening of the tendo Achillis - arthrography of the talocrural and talonavicular joints should be performed. This can be done as early as the age of 2 months, but is easier at 6 or later.

Incomplete correction or recurrence is a clear indication for operation, and a decision can be made on the basis of the examination alone. On the other hand, examination is not sufficient to determine the type of operation required, that is whether osteotomy is necessary or not. Adequate muscular function, however, will be

concerning the need for and extent of surgical procedures

On arthrography the degree of flattening of the trochlea can be measured by means of the radius (R/L) and the degree of obliteration of the joint by a central angle (α) (see Figure 1a).

The deformity of the talonavicular joint, the obliteration of its recesses, as well as the medial or plantar displacement of the talus bone, can also be assessed. Further, it is observed whether the neck of the talus deviates off medially or deviates in the lateral direction, or both, in relation to the long axis of the foot.

Arthrograms have revealed that the deformity in clubfoot can vary considerably.

It is therefore not possible to make a simple and practical classification of the deformity based on arthrographic findings. Each case must be analysed individually (Hjelmstedt & Sahlstedt 1978). For this reason our indications for different surgical procedures are presented here on

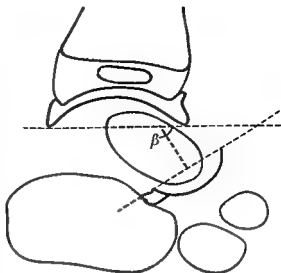


Figure 1b Measurement of the plantar deviation (β) of the talonavicular joint. The base line of the talonavicular joint is drawn through the upper and lower capsular attachment of the joint and the plantar oriented recess marking the borderline of the anterior subtalar joint.

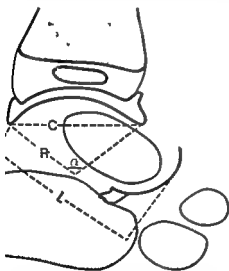


Figure 1a Arthrogram of a clubfoot talus talar drawing. Lateral view. Measurement of the radius (R) of the talus and the radius (R) and cord (L) of the trochlea. The central angle (α) of the trochlear recess. The cord (C) is tangential to the anterior and posterior ankle recesses. The central angle is measured with a protractor. The curve of the trochlea is approximated to the arc of a circle.

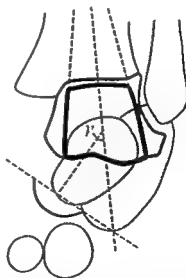


Figure 1c Dorso-plantar view of the foot. Measurement of the medial deviation (γ) of the talonavicular joint. The base line of the talonavicular joint is drawn through the upper capsular attachment of the joint. The required angle (γ) is the angle between its normal and the long axis of the trochlea.



Figure 2 Congenital clubfoot in a 6 month old boy. Simultaneous arthrography of the talocrural and talonavicular joints. The trochlea is normally rounded and its curvature has a normal central angle. The recesses are fairly good. The talus is in a moderately equinus position.

the basis of cases with varying degrees and types of dysplasia. To simplify this survey, arthrograms from children aged 3 months to 8 years have been chosen.

Figure 2 demonstrates an equinus deformity in a case with a well rounded trochlea, a relatively large central angle and



good recesses. Lengthening of the Achilles corrected the deformity.

The arthrogram in Figure 3 shows a plantar deviation of the head and neck of the talus even in full dorsal extension of the foot. In such cases the equinus deformity is corrected only by wedge osteotomy of the neck of the talus.

Figure 4, in the dorso-plantar view, illustrates a case with only a slight displacement of the navicular bone. Correction can be achieved by len-

Figure 3 Congenital clubfoot in a 14-month old boy. Simultaneous arthrography of the talocrural and talonavicular joints.

- Lateral view. The trochlea is rounded ($R/L = 0.40$). The recess is normal. There is marked plantar deviation of the head and neck of the talus (35°).
- Dorso plantar view. The talonavicular joint is deviating slightly in the medial direction (25°).

the tibial tendon in some cases and with plantar fasciotomy and release of the adductor hallucis muscle. Figure 5 depicts marked medial and plantar displacement of the navicular bone and some angulation of the head of the talus. The talonavicular joint is not notably obliterated and open reduction of the navicular

bone to its original position is considered possible. Osteotomy is thus not indicated.

Figure 6 also demonstrates marked medial and plantar displacement of the navicular bone but in this case the talonavicular joint recesses are obliterated. Surgical reduction of the navicular bone is considered hardly possible. Further, if this reduction were incomplete, the navicular bone would certainly become displaced again. Wedge osteotomy is indicated.

The arthrogram in Figure 7 shows marked flattening of the talar trochlea combined with plantar medial deviation of the head of the talus and displacement of the navicular bone. Here there are clear indications for correction osteotomy.



• 4 Congenital clubfoot in a 15 month-old simultaneous arthrography of the talocrural and talonavicular joints. There is spontaneous first filling of a postero-medial tendon sheath. Lateral view. The trochlea displays normal rounding. The recesses are diminished. The medial angle (α) of the trochlear curvature is increased (124°). The neck and head of the talus are deviating moderately in the plantar direction ($\beta = 38^\circ$). Medio-plantar view. The talonavicular joint is deviating moderately in the medial direction ($\gamma = 44^\circ$) but the articular surface of the talar head is normally rounded.





a

7 years

flattened ($R/L = 0.47$). The ankle recesses are diminished. The central angle of the trochlear curvature (α) is small (101°). The neck of the talus and the talonavicular joint are clearly deviating in the plantar direction ($\beta = 45^\circ$).

- b) Dorso-plantar view. The talonavicular joint is deviating considerably in the medial direction ($\gamma = 60^\circ$). The articular surface shows fairly normal rounding, however, and the ankle recesses are retained. Open reduction of the navicular bone is therefore considered possible.

SURGICAL PROCEDURES

Talo-calcaneal osteotomy is always combined with soft tissue operations. If the tendo Achillis is to be lengthened, however, this should not be done at the same operation as the osteotomy but at a separate session either before or after. Neither should transfer of the anterior tibial tendon be performed at the same time as the osteotomy, but at a later session. Some time should be allowed to elapse between the different sessions, so that the patient has time to activate the muscles and increase the mobility.

If osteotomy is to be performed, the talonavicular joint should not be opened, as this may lead to avascular necrosis of the talar head. It is therefore necessary to decide before the operation whether or not osteotomy is to be carried out.

The operations are always performed in a bloodless field.

Operation session I

An incision is made on the medial aspect of the foot from the base of the first metatarsal to the malleolus and then proximally behind it. The posterior tibial tendon is freed from the malleolus and then divided in a Z-shaped fashion. This tendon is also identified close to its insertion on the navicular bone and the distal part of the divided tendon is pulled down three centimeters on to the foot. The tibionavicular ligament is then divided and the neck of the talus is freed medially, dorsally and at the posterior aspect without opening the talonavicular joint.

The lacinate ligament is divided and the blood vessels are carefully held apart. The plantar fascia is freed at the calcaneal tuberosity and divided close to its insertion. The flexor hallucis muscle is then released from the calcaneal tuberosity and from the medial aspect of the calcaneus by careful dissection, avoiding damage to the blood vessels and nerves. The wound is closed with most compress.

An incision is now made over the medial aspect of the foot from the base of the first metatarsal to the malleolus and then proximally behind it.



5) Congenital clubfoot in a boy age 2 years at simultaneous arthrography. Anteroposterior view. The trochlea of the talus is slightly flattened. The central angle of the talar curvature (α) is slightly reduced (66°). The ankle joint recesses are diminished. The talonavicular joint displays clear deviation in the plantar direction ($\beta = 51^\circ$).



6) Dorsoplantar view. The talonavicular joint is deviating greatly in the medial direction ($\gamma = 66^\circ$). The ankle joint recesses are largely obliterated. Wedge osteotomy is indicated.

port extensor muscle of the toes is released desired extent from its insertion. The neck of the talus is then freed laterally and dorsally and a rich retractor is placed around the neck. A knife and chisel a wedge is removed as in Figure 8. It is seldom possible to remove a wedge of more than 45° to 50° . Thus, full correction cannot always be achieved in extreme cases.

A rich retractor is applied around the talus medial to the peroneal tendons. A wedge of bone is then removed with a chisel, to correct the curvature deformity and to shorten the talus to some extent. Care should be taken not to make the bone defect too large.

The osteotomy surfaces are now pressed together at the same time as the distal part of the

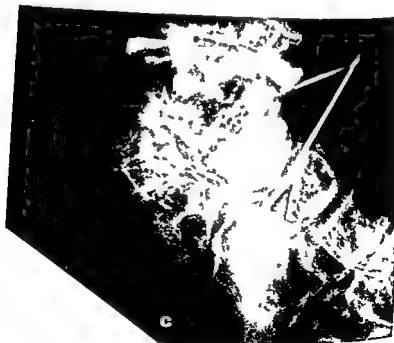
foot is pronated. Now it can be seen whether the osteotomy needs to be adjusted. Further the position of the toes at full correction is checked. If they are locked in a flexed position then the long flexor tendons of the toes should be lengthened to avoid any later cavus deformity.

If the peroneal tendons seem very flaccid at full correction they are usually shortened with zig-zag sutures, partly to give them some tension and partly to reduce the risk of their adhering in the osteotomy site during healing.

The distal part of the posterior tibial tendon is

1) The tendons are sutured with desired lengthening.

The subcutaneous tissue and skin are closed with angle sutures. Suction drainage is applied in both wounds, to reduce postoperative swelling which may otherwise be considerable.





' Secondary clubfoot in an 8 year old boy
na bifida Simultaneous arthrography
ral view The trochlea of the talus is
mally flattened and the ankle recesses are
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d) After talar and calcaneal osteotomy the
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should be slackened slightly
vation a plaster cast cut longitudinally is
with the foot in the desired correction
knee flexed 90° The limb is elevated for
ys. Postoperatively the foot is carefully
d for swelling and any circulatory changes
plaster cast is changed within 7 days, with
correction or overcorrection of the foot
al length of immobilization is 8 to 9 weeks.
us time good healing of the osteotomy lines
ly seen at radiological examination
rule the patient is then given a splint for
ion 11 night and a shoe insertion for use in
time

Operation session II

At this operation complementary procedures are carried out Lengthening of the tendo Achillis is often performed before the osteotomy but in some cases afterwards

It is relatively common that the anterior tibial muscle despite good correction of the foot deformity functions as a supinator If the patient sits relaxed with the foot dependent and on instruction dorsiflexes the foot it is clearly seen how the foot is first supinated by the anterior tibial muscle and is then dorsiflexed In these cases either the entire tendon has been transferred to the middle of the dorsal aspect of the foot or the tendon has been divided longitudinally and half of it has been transferred to the lateral aspect of the foot The latter procedure was described by Baumann (1970) and good results have been reported

In extreme cases the skeletal correction has not always been quite satisfactory and slight supination and a certain degree of adduction have remained In such cases the early skeletal correction has been complemented by wedge osteotomy through the cuboid as depicted in Figure 9 a-d.

DISCUSSION

In an anatomical and functional investigation of clubfoot specimens we found that on dorsiflexion of a greatly deformed talus an incongruence in the talocrural joint occurs Further we pointed out that "due to the deformation of the articular facets of the talar head the navicular bone may after reposition have only a very small supporting area with a consequent great risk of relaxation" (Hjelmstedt & Sahlstedt 1974a) As a solution to these problems we proposed a corrective osteotomy

After 8 years' experience of arthrographic analysis of the talar deformity in clubfoot and 6 years' experience of correction osteotomies, we are still convinced that osteotomy is an essential part of the treatment plan in a small selected group of refractory clubfeet

The method presented here is the one which with our increasing experience we have found to be the best It has often been necessary to diverge from the treatment plan for the reason that different types of operations have been performed before the patient has been referred to us Furthermore,

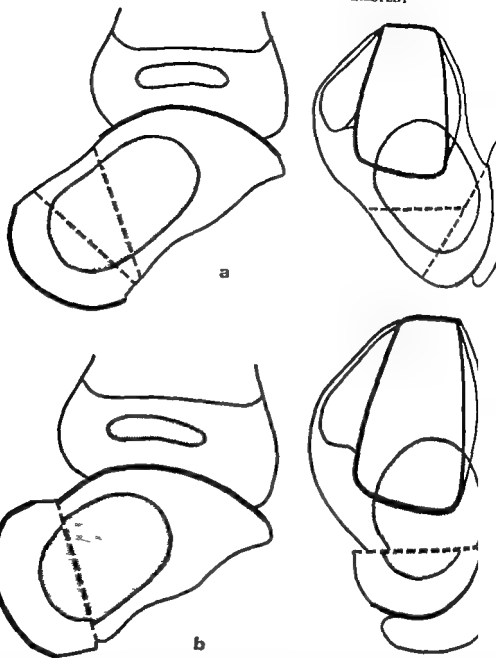


Figure 8 a) Lateral view of a clubfoot talus. Note the flattening of the trochlea and plantar deviation of the neck and head. The osteotomy lines are marked with short dashes. The base of the wedge should as a rule be on the dorso-lateral side of the talar neck.

b) Correction after wedge osteotomy.

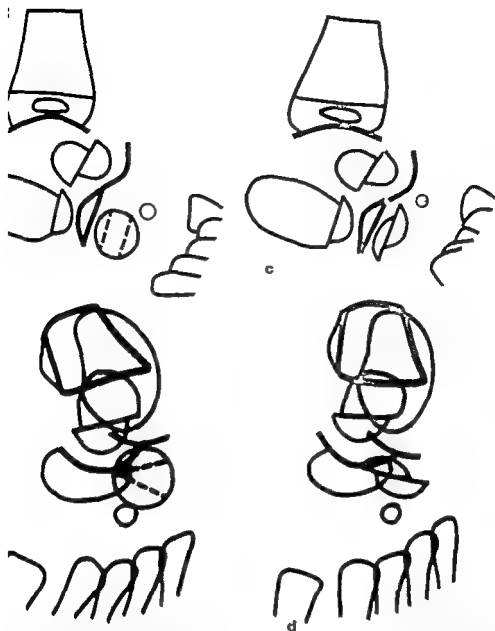
in the beginning we were somewhat uncertain about the planning of an adequate form of treatment.

Skin necrosis at the margins of the medial wound is a risk that must always be taken

c) A clubfoot talus and the navicular above. The joint borders are marked by broad lines and the osteotomy lines by short dashes. Note the pronounced wedging of the talar neck and head and the shape of the original talonavicular joint.

d) Correction after osteotomy.

into consideration, but this has been avoided by the precautionary measures mentioned above. It has also been possible to guard against wound infection. In case of extreme talar deformity, however, it



a) and b) Schematic drawing of a clubfoot after talar and calcaneal osteotomy. Planned wedge ∇ through the cuboid bone is indicated with a broken line. The base of the wedge is oriented

Correction after osteotomy

of the talar occurred (Figure 10). As variation time to date in this patient is few years, it is too early to say this complication will affect the final but hitherto the child has not had any

Considerable scar formation might be expected after several extensive operations. In the beginning we were in fact restrictive with soft tissue procedures in connection with osteotomy, and as a consequence the complementary operations in session II became



more extensive. It has been found that even after relatively large operations wounds have healed without leaving contracting scars, and the treatment described can thus be recommended in this aspect as well.

CONCLUSIONS

Indications for correction osteotomy are based upon an arthrographic analysis of the anatomy.

Osteotomy is indicated in only a few cases of clubfoot.

Correction osteotomy is only one part of a comprehensive treatment plan.

With the described planning of the operation and treatment, and with observance of all details of the procedure, the risk of complications is small and the correction achieved is generally good.

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Figure 10 a) and b) Avascular necrosis in the head of the talus 2 years after wedge osteotomy in a case of secondary clubfoot.

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D-CALCANEAL OSTEOTOMY AND SOFT-TISSUE PROCEDURES IN THE TREATMENT OF CLUBFEET

Results in 36 Surgically Treated Feet

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Thirty-six refractory or recurrent clubfeet were treated by correction osteotomy through the talar neck and calcaneus in combination with various soft tissue procedures. The aim of the osteotomies was to correct the pronounced deformities observed at simultaneous arthrography of the talocrural and talonavicular joints. The soft tissue procedures were carried out to facilitate the correction and to prevent recurrence by creating muscle balance.

Twenty-four clubfeet were idiopathic and 12 were secondary to neurological or other diseases. The observation period since the osteotomies were performed was, at the time of writing, 1.5 to 5.5 years (median 3 years). A brief report of the indications and methods of operation is given.

Good or fair results were achieved in 21 of the 24 idiopathic clubfeet, while the results were somewhat poorer in the secondary clubfeet. A correlation between the degree of arthrographically demonstrated talar deformity and the results of surgical treatment was found.

The main reason for a poor result was incomplete correction of the most extreme talar deformity in combination with marked preoperative joint rigidity.

Key words: arthrography, clubfoot, osteotomy, soft tissue procedures

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ated cases of refractory or recurrent clubfeet, correction osteotomy through the talar neck and the calcaneus has constituted an important part of the treatment. As an average of 3 years has now elapsed since the first 36 operations were performed, the preliminary results in these cases will now be presented.

In the present study, the treatment in a number of these cases deviated in certain respects from that recommended in the foregoing article and also from the recommended treatment plan, so we considered it appropriate to present our results in a separate report.

The deviations do not refer to indications for operation or operative principles, however, but to the time of operation and to

technical details in the surgical procedure. One main reason for the deviations in the initial cases of the series was lack of experience at that stage.

PATIENTS

There were 16 patients with 28 idiopathic clubfeet and 9 patients with 14 clubfoot deformities secondary to spina bifida (6), spastic paresis (2), malformation syndrome (1), arthrogryposis (2) and sacral agenesis (1).

Osteotomy was performed on 24 of the idiopathic clubfeet and in 12 of the secondary clubfeet.

The sex and age distributions and the observation times after osteotomy in the two groups are given in Table I.

	Series of idiopathic clubfeet	Series of secondary clubfeet	Total
Number of boys	13	4	17
Number of girls	3	5	8
Total number of patients	16	9	25
Number of osteotomized feet	24	12	36
Number of feet treated by other methods	4	2	6
Total number of clubfeet	28	14	42
Median age at osteotomy (years)	17	48	19
Min and max ages at osteotomy (years)	04 — 67	04 — 83	04 — 83
Median obs. time after osteotomy (years)	30	38	34
Min and max obs times (years)	15 — 55	15 — 53	15 — 55

The group of osteotomized idiopathic clubfeet is selected and comprises cases where conservative and, as a rule, also operative treatment had not given satisfactory correction, or where the deformity had recurred (Table 2).

The number of osteotomized secondary clubfeet is, for natural reasons, smaller than the number with a congenital deformity (Table 2). The median age at osteotomy was relatively high (48 years) in these secondary cases. One reason for this was that treatment of urinary tract infection and/or hip and knee contractures had been given priority over foot correction.

All 36 feet had a pronounced or extreme clubfoot deformity before the osteotomy, with varying degrees of limitation of movement in the talocrural and subtalar joints and in Chopart's joint.

Before the osteotomy simultaneous arthrography of the talocrural and talonavicular joints

was performed routinely by the method described by Sahlstedt (1976a,b). The use of this method for measurement of the deformities has been investigated previously (Hjelmstedt & Sahlstedt 1976) and has been found good or fair for the variables in question. Normal values and an analysis of mean values from a material of clubfeet have been reported by Hjelmstedt & Sahlstedt (1976).

The variables measured and the values are presented in Table 3 with normal values for comparison, and the methods of measurement are illustrated in Figure 1a-c in the foregoing (Hjelmstedt & Sahlstedt 1979). It is seen in Table 3 that the mean values for the clubfeet deviated considerably from the normal values.

The indications for correction were as follows:

A The clubfoot deformity had not

Table 2 Treatment given before the osteotomy. The material is selected and consists of clubfeet which were not adequately corrected after the treatment described in the Table.

Treatment	Number of idiopathic clubfeet	Number of secondary clubfeet	Total
Conservative treatment alone	6	6	12
Lengthening of tendo Achillis alone	7	1	8
Lengthening of tendo Achillis + other soft tissue procedures	10	5	15
Tibial osteotomy	1	12	13
Total number of clubfeet	24	24	48

Results of the radiographic measurements of talar variables in the osteotomy series R — radius rochlear curvature and L — length of the talus The measurement methods are illustrated in la-c of the foregoing paper (Hjelmstedt & Sahlstedt 1979) With 90 per cent confidence 95 per cent normal population will fall within the tolerance limits The means of the variables in the set are all pathological The individual values vary considerably and some are very extreme

	Preoperative values for idiopathic clubfeet n = 24		Preoperative values for secondary clubfeet n = 12		Normal values n = 54 95 per cent tolerance limits	
	mean	range	mean	range	mean	
Index of the ang of the a	0.47	0.38–0.85	0.48	0.35–0.74	0.35	0.29–0.42
angle α of the ar curvature	108°	143–53°	102°	142–64°	154°	173–135°
Deviation β of the vicular joint	47°	26–65°	53°*	33–84°	24°	14–35°
Deviation γ of the vicular joint	52°	18–78°	55°	31–90°	15°	8–22°

es that the plantar deviation could not be measured on 2 of the 12 feet

actorily corrected by previous treatment
id recurred
presence of pronounced medial or plantar
tion or both of the head and neck of the
plantar medial dislocation of the
ular bone and such marked deformation
talonavicular joint that a reduction of the
ular bone to its original position was not
dered possible (Figure 1a,b)

The indications for operation are described and illustrated in greater detail in the foregoing paper (Hjelmstedt & Sahlstedt 1979)

The aim of the operation was to correct as much as possible of the foot deformity retaining the mobility of the different joints, by means of wedge osteotomy through the talar neck and calcaneus (see Figure 2)

The simultaneous soft tissue procedures were

The soft tissue operations that were performed in conjunction with talo-calcaneal osteotomy (see section 1) In 23 feet the tendo Achillis had been lengthened on a previous occasion and in 6 posterior tibial tendon had been lengthened divided or transferred previously (see Table 2)

Age at operation (years) median	Lengthening of				Shortening of one or both peroneal tendons	Plantar fasciotomy + release of abd hallucis muscle
	tendo Achillis	post. tibial tendon	tendon of flexor dig communis	tendon of flexor hall long		
17	4	21	11	8	9	18
48	2	9	1	3	1	5
19	6	30	12	11	10	23



Figure 1 Arthrography of the talocrural and talonavicular joints in an 18-month-old child with severe clubfoot deformity

a Lateral view Note the pronounced flattening of the trochlea and the plantar deviation of the talonavicular joint $R/L = 0.46$ $\beta = 44^\circ$ Normal values $0.29-0.42$ and $14^\circ-35^\circ$, respectively

b Dorso-plantar view There is considerable medial deviation of the talonavicular joint R/L value $8^\circ-22^\circ$

undertaken to facilitate the correction and to prevent recurrence by improving the muscle balance. The extent of these procedures was determined by the preoperative clinical status and an evaluation during the course of the operation. The soft tissue operations performed in conjunction with the osteotomy are given in Table 4. These combined operations are referred to as session I.

Transfer of half or the whole of the anterior tibial tendon to the lateral part of the dorsal aspect of the foot was often indicated in order to reduce the tendency to supination and to increase the power of dorsal extension. It was considered unsuitable to do this at the same operation as the talo-calcaneal osteotomy and it was therefore performed when necessary at a second session, on average 1.5 years after the first. A wedge

resection through the cuboid bone was also carried out at the same time (see Table 5).

The arthrographies generally showed that preoperatively the patients were able to move the foot as much as the deformed tibia allowed. Thus in these cases lengthening of the tendo Achillis would not increase the range of motion at the ankle joint. There were two exceptions, however, and in these two the tendo Achillis was therefore lengthened at session 5 months after the first operations performed in session I or II (see Table 5).

The operative technique as it has been developed with increasing experience over the years is described in detail in the literature (Hjelmstedt & Sahlstedt 1979).

RESULTS

All osteotomized feet showed a marked deformity of the talus and its joints pre-operatively (Table 3 and Figure 1a-b). The aim of the osteotomy was to correct the plantar and medial deviations of the talar neck and head and the calcaneal deformity. The deformity of the talocrural and talonavicular joints remained unaltered, of course, as well as the other skeletal deformities. It could not be expected, therefore, that in any of the patients full mobility would be achieved in all joints or full correction of that part of the adductor and supination deformities caused by skeletal dysplasia distal to the navicular and cuboid bones.

This meant that a "very good result" as defined in Table 6 would only be possible in a minority of cases. In cases with severe deformity of the talocrural joint it was hardly likely that a better result than "fair" would be obtained.

The evaluation of the treatment results 15-55 years after the osteotomy is based upon the clinical examination. Routine arthrography at follow-up was not considered possible. The criteria for classification of the results in the idiopathic clubfeet are given in Table 6. For the secondary clubfeet the evaluation had to be made against the

2 Photograph taken during wedge
ny through the talus and calcaneus. The
in the lower left corner and the toes to the
he incision has been made over the tarsal
l greatly angulated wedge has been excised
e neck of the talus. A less angulated wedge
being removed from the calcaneus with an
ne. The short extensor muscle of the toes
as been partly released from its insertion,
to the right of the wound.

5 The procedures carried out at operation session II in 13 of the 24 osteotomized idiopathic
The time interval between session I and session II ranged from 4.5 months to 3 years (median
1.5 years). In the group of secondary clubfeet two feet underwent lengthening of the tendo Achillis in a
session and in a case of arthrogryposis with a poor functional result triple arthrodesis was
performed later.

Median age at operation session II	Procedures at operation session II				
	Transfer of		Lengthening of tendo Achillis	Shortening of the peroneal tendons	Wedge osteotomy through the cuboid
	The whole ant tib tendon	Half the ant tib tendon			
2.8 years	4	9	2	2	8

Table 6 Classification of the treatment results according to the criteria given in Table 5. The talus was

	Result of treatment			
	Very good	Good	Fair	Poor
Dorsiflexion of the foot	10–15°	5–10°	0–5°	<10° etc.
Plantar flexion of the foot	≥20°	≥15°	≥10°	reduced
Mobility of subtalar joints	good	possibly slightly reduced	reduced	reduced
Mobility of mid-tarsal joints	good or hypermobile	good, possibly hypermobile	relatively good	reduced
Deformity on weight-bearing				
equinus	—	—	—	+
varus	—	—	—	— or +
adductor	insignificant	<15°	≥15°	+
Gait without shoes	good	good	fair	poor
Gait with shoes	good	good	good	fair

background of the patient's basic disease—thus the classification in these cases was more subjective.

The results of the treatment are presented in Table 7. Good or very good correction and function according to the criteria in Table 6 were achieved in 17 of the 24 idiopathic clubfeet (70.8 per cent) and a fair result in 4 (16.7 per cent). In the secondary clubfeet the results were poorer, as expected in view of the less favourable original condition in these cases (Table 3).

The result was regarded as poor in 3 of the 24 idiopathic and 4 of the 12 secondary clubfeet. There were two principal reasons for the poor results. In some cases with severe skeletal deformity it was not possible to remove a sufficiently large wedge from the talus to achieve full correction. In particular a residual equinus of up to 10° gave a functionally unfavourable result. The second reason, which as a rule was combined with

the first, was pronounced rigidity of the talocrural, subtalar and Chopart's joints. If this was already present preoperatively, some of the secondary and in some idiopathic clubfeet.

As shown in Tables 8 and 9 the degree of talar deformity correlated with the therapeutic result.

In seven feet a policy of expectant management was followed for 1.5 years or longer before II was undertaken. The aim of this was to see whether there was any regression of the residual adductor and/or supinator deformity after treatment with a shoe insert and night splints. No appreciable improvement was noted.

Despite the fact that session I entailed a relatively extensive operation, that session was carried out in many cases, and the feet were immobilized for a total of 6 weeks, no definite reduction of the deformity of the joints was observed. On the other

Table 7 The functional result 1.5–5.5 years (median 3.2 years) after the osteotomy, according to the criteria given in Table 6

	Very good	Good	Fair	Poor	Total
Idiopathic clubfeet	7	10	4	3	24
Secondary clubfeet		4	4	7	15
Total	7	14	8	10	39

Comparison between measurement data obtained at arthrography before talo-calcaneal fusion and the results of treatment in the idiopathic clubfoot R/L. — index of the flattening of the arch — central angle of the trochlear curvature, β plantar deviation and γ medial deviation of the subtalar joint. The method of measurement is shown in Figure 1a-c of the foregoing paper (Hjelmstedt & Sahlstedt 1979)

Treatment result	No. of feet	Arthrographic variables			
		R/L	α	β	γ
Good	7	0.44	116°	52°	47°
	10	0.45	113°	47°	51°
	4	0.49	101°	46°	52°
	3	0.56	77°	41°	69°

Comparison between measurement data obtained at arthrography before talo-calcaneal fusion and the results of treatment in the secondary clubfoot. For explanation of variables see Table 8

Treatment result	No. of feet	Arthrographic variables			
		R/L	α	β	γ
Good	4	0.42	116°	44°	45°
	4	0.46	105°	49°	68°
	4	0.57	87°	65°	52°

In some cases a certain degree of mobility of the mid-tarsal joints is needed.

After operation wounds healed without infection or necrosis and with no contracture. In one case avascular necrosis occurred in the head of the talus postoperatively.

DISCUSSION

In our previous study (Hjelmstedt & Sahlstedt 1979) we showed that there is some correlation between the central angle of the trochlear curvature (α) and flattening of the trochlea, the angle decreasing when the flattening becomes more pronounced. It seems that there are no or only weak correlations between the different arthrographic measurable variables. This means that a simple and practicable classification of clubfoot according to the type and degree of deformity is not possible and that all

clubfeet must therefore be treated on an individual basis.

The poor correlation between the different variables also means that the forces causing the talar deformity vary from case to case with respect to magnitude and direction and probably also duration. In the neurological cases we know that the muscle forces deviate from the normal. The nature of the deformation forces in the idiopathic cases is not known, but it is probable that the mechanism is similar, i.e. that the normal muscle balance is disturbed. With time, of course, weight-bearing will also play a part in the further development of the deformity.

From this viewpoint the restoration of the muscle balance will be one of the prerequisites for successful treatment, and this can only be achieved by measures that vary in the individual patient.

In the simplest cases muscle balance is attained by conservative treatment alone with reduction of the navicular and cuboid bones, i.e. by normalizing the direction of the muscle forces. In the more refractory or recurrent

clubfoot this is not sufficient, and in these cases balance between the muscle forces has to be created by surgical procedures such as open reduction of the navicular bone and lengthening, shortening and transfer of different tendons.

However, there is a minority of idiopathic clubfoot in which the skeletal deformity is so pronounced that soft tissue procedures alone are insufficient to create a balance of muscle power. In such cases the direction and magnitude of the muscle forces can only be normalized by soft tissue procedures combined with corrective bone operations. As reported by Settle (1963), Irani & Sherman (1963), Reimann (1967) and Hjelmstedt & Sahlstedt (1974), among others, severe skeletal deformity can be present at birth. For practical reasons, however, arthrography and operation cannot be performed immediately but have to wait until the child is at least about 6 months old. Talo-calcaneal osteotomy is not a routine method in the treatment of clubfoot, but is only indicated in 10–15 per cent of idiopathic cases (Hjelmstedt & Sahlstedt, 1980). The primary treatment of clubfoot should always be conservative, as this gives a good result in a large proportion of the cases.

In some cases the osteotomy was performed at 5–6 months. The operation proved to be relatively difficult, however, at this early age, and it is preferable to wait until the child is at least 9 months old.

If it is nevertheless considered necessary to lengthen the tendo Achillis at an earlier age, this should be preceded by arthrography so that a more complete treatment plan can be drawn up. It should be the principle to map out the anatomy before any type of surgical operation.

The osteotomies healed in 8 to 9 weeks. Thereafter a shoe with an insertion was worn and also, as a rule, a night splint. In the beginning the patient should be followed up at intervals of 2–3 months. If full muscle balance has not been achieved, complementary operations should be performed (Table 5).

The only complication noted was avascular necrosis of the head of the talus in one case. After opening the talar head and the trochlea from the supply through vessels in the talar-talocrural and talonavicular joints, therefore important to avoid the capsule at the operation. In the most severe deformities, however, difficulty may be encountered in having generally rather rigid joints, when the capsule may be inadvertently opened.

In cases with marked lateral deviation of the trochlea, an extremely small medial head and neck of the talus, severe correction was not always obtained by osteotomy (Tables 8 and 9). These were described as "poor" in accordance with given criteria. The only alternative treatment in these extreme cases was to be triple arthrodesis. As this was done on small children, talo-calcaneal osteotomy may be justifiable even in cases as a temporary measure either for a suitable time for arthrodesis.

Because of the necessity for pre-operative arthrographs, and because of the individualized surgical measures, in our opinion all operations on clubfoot are centralized.

CONCLUSIONS

Wedge osteotomy through the talar-talocrural joint allows correction of the severe deformity of the calcaneus in refractory clubfoot.

Correction osteotomy may be combined with lengthening and shortening of the anterior tibial tendon in order to achieve muscle balance.

For practical reasons these operations often need to be divided into two stages with an interval of 5 to 6 months.

The plan of operative treatment here should only be applied to a few

cases and the indications for are based largely upon the findings operative simultaneous arthrography of crural and talonavicular joints.

selected material of 24 refractory or idiopathic clubfeet with pronounced deformity a good or fair result was obtained in 21 feet (87.5 per cent). The result somewhat poorer in a smaller series of secondary to neurological or other causes.

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MEETINGS OF DANISH ORTHOPAEDIC SOCIETY

27-28 April, 1979

N J HOLM

OR McLAUGHLIN IN INTERIC FRACTURES?

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A prospective, randomized study 146 con-
trochanteric fractures treated either with
nails or McLaughlin nail and plate were
studied. The mean age was 76 years.
Operation time, operating time and the duration
of hospitalization were almost equal in the two
groups. During the first postoperative month there
were 3 deaths in the McLaughlin group and
1 in the Ender group.

Patients treated with Ender pins had
fewer problems and 10 needed reoperation.
Infection occurred after two McLaughlin
nails.

1 year later the situation concerning pain and
function in the hips was almost identical in the
two groups.

MENT OF FEMORAL NECK FRACTURES IN A DEPARTMENT OF ORTHOPAEDIC SURGERY

P A Frandsen
Department, Varde Hospital

A study of 145 patients with fractures of the
femoral neck (53 dislocated medial, 69
stable and 23 stable), treated in a surgical
department, are reviewed.

Cumulative mortality 11 months
after surgery was 18.5 per cent, between 6 to 12
months 26 per cent died, thus equalling the
mortality for this age group.

Prophylactic anticoagulation reduced the
mortality rate from 25 to 10 per cent ($P < 0.05$).
Two per cent of the patients were able to
leave the hospital at the time of leaving the hospital.
The authors concluded that the mortality rate is no
greater than that reported for other series of
patients with this type of fracture.

THE PROGNOSTIC VALUE OF PAUWELS' AND GARDEN'S CLASSIFICATIONS OF MEDIAL FRACTURES OF THE FEMORAL NECK

P A Frandsen & E Frigaard

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In a study of 265 consecutive cases of medial
fracture of the femoral neck the classifications of
Pauwels and Garden were compared in order to
determine which is the better system of classifica-
tion. In all three groups Pauwels' classification
showed almost the same frequency of healing
($P > 0.05$, Chi square test). However, Garden's
classification gave a reliable statement concerning
the prognosis of the different types of medial
fractures of the femoral neck ($P < 0.0001$, Chi
square test). Therefore the authors recommend
that only Garden's classification should be used.

THE INCIDENCE OF MEDIAL FRACTURES OF THE FEMORAL NECK

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In a population of 230,000 the incidence of
medial fractures of the femoral neck related to sex
and age was determined. The determination was
based on 156 fractures treated during a 2-year
period. For the same period the incidence was
compared with the total incidence of medial
fractures of the femoral neck.

The incidence was the same for men and women, but above the age of
60 years the incidence in women was greater by a
factor of three compared with that in men.

$$\begin{aligned} & \frac{\partial}{\partial t} (\rho u) + \frac{\partial}{\partial x} (\rho u^2) = -\frac{\partial p}{\partial x} \\ & \frac{\partial}{\partial t} (\rho v) + \frac{\partial}{\partial y} (\rho v^2) = -\frac{\partial p}{\partial y} \\ & \frac{\partial}{\partial t} (\rho w) + \frac{\partial}{\partial z} (\rho w^2) = -\frac{\partial p}{\partial z} \end{aligned}$$

THE IMPORTANCE OF THE ANGLE BETWEEN THE FRACTURE LINE AND THE NAIL IN MEDIAL FRACTURES OF THE FEMORAL NECK

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In medial fractures of the femoral neck treated with a single nail one would expect from a mechanical point of view that the rotatory stability of the fracture would be at its lowest when the angle between the fracture line and the nail was 90 degrees. This hypothesis was tested in a consecutive series of 197 displaced medial fractures of the femoral neck. The results showed significantly better healing ($P < 0.025$, Chi square test) when the angle between the nail and the fracture line, as measured on a frontal radiograph, was less than, as opposed to more than, 80 degrees.

HIP FRACTURES A PROGNOSTIC EVALUATION OF THE NECESSARY HOSPITAL RESOURCES

J Steen Jensen & E Tønderold

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A total of 1,592 patients over the age of 50 years with hip fractures were examined. The incidence of hip fractures was found to increase exponentially with age and to be twice as prevalent in females. The percentage of femoral neck fractures decreased with age in females but was independent of age in males.

From 1971-1977 the number of hip fractures increased by 12 per cent yearly. Based on the prognosis for the population the expected increase is 3 per cent yearly until 1992. This means a doubling of the number of hip fractures over a 15-20 year period.

The hospitalization time decreased from 30 days to 21 days during the period investigated.

With unchanged results of the fracture treatment and a hospitalization time of 20 days about 20 per cent of the total number of orthopaedic beds in the area will be occupied by patients with hip fractures in the middle of the 1980's.

The number of technical failures for the different methods of treatment was analyzed and it was concluded that the demand for extra hospital beds could be overcome by using the safest possible methods of treatment.

MECHANICAL STRENGTH AND OF FAILURE OF JEWETT AND McLAUGHLIN HIP IMPLANTS

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Load tests of Jewett and McLaughlin hip implants manufactured from Cr-Co-Mo 28-32

Jewett implants had a yield strength of 870-1500 N due to bending of the neck. The 125° and 135° implants were stronger than the 140° and 145° because of the design of the neck.

In McLaughlin implants the strength was dependent of the nail plate angle. Two points were observed. The two high points were 750 N, respectively, were due to the nail and the curved extension of the plate. The lowest yield point of 250 N was due to deformation of the knobs on the distal nail. The curved plate extension and the interposed washer were also deformed in a looseness of about 10° at the junction.

A design change was proposed to the implant to be used for the more unstable trochanteric fractures, which transmit a load of about five times weight during level walking.

DIFFERENTIAL HISTOCHEMICAL STAINING OF GLYCOSAMINOGLYCANS IN THE MATRIX OF OSTEOARTHRITIC CARTILAGE

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The distribution of chondroitin-6-sulphate and keratan sulphate in osteoarthritic cartilage has been analysed in a histochemical study using Safranin O, Alcian Blue-CEC and toluidine blue at different pH values. In addition to the presence of glycosaminoglycans, osteoarthritic cartilage is characterized by increased amounts of chondroitin sulphate, especially in the form of clusters. In the control cartilage the chondroitin sulphate was found in the weight-bearing zone of the cartilage, or in cartilage with moderate osteoarthritis. The cartilage of severe osteoarthritis was made up almost entirely of chondroitin sulphate.

These findings are in accordance with the increase in the rate of ^{35}S incorporation into the cartilage matrix.

MEETINGS OF FINNISH ORTHOPAEDIC ASSOCIATION

Helsinki, Finland, March 10, 1979

A. ALHO

ULTRASONIC CUTTING OF BONE

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Ultrasonic cutting of bone has been reported to have some advantages (accuracy, decreased intraoperative space, smooth bone edge) over conventional oscillating and rotatory cutting. The purpose of the present study was to determine the immediate effects on bone and periosteum of an ultrasonic saw (URSK 7, Ultrasonic, USA) compared with those of an oscillating saw.

Surfaces of rabbit ulnar and scapular bone were prepared immediately after surgery for scanning electron microscopic (SEM) and histological studies.

It was easier to control the osteotomy line by the ultrasonic cutting whereas the cutting speed of the oscillating saw was greater than that of the ultrasonic saw. Histologically the differences were small and the amount of thermal necrosis of the bone was equal and independent of saline cooling. Observations revealed that the ultrasonic saw cut rather rough surfaces and the periosteum became elevated. Osteotomies made by the oscillating saw showed some microfractures and parallel grooves, but the surfaces were flatter. The edge of the periosteum was not affected as it was by an ultrasonic saw.

ANTEROLATERAL SPINE FUSION AND RESECTION OF 80 CONSECUTIVE CASES

Yrjö Järvelin, P. Salenius, P. Pylkkanen & P. Järvelin

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During the period 1972-1976 37 women and 43 men were treated surgically. Their mean age was 30 years. The indications for surgery were spondylolysis and spondylolisthesis in 73 cases, and instability in seven. One vertebral interval was fused in 60 cases and several fused in 20. The period spent in bed after surgery was usually 2-4 weeks (44 patients). A questionnaire was sent to the patients between 1 and 5 years after surgery.

Pain was recorded before surgery at stress in all patients and at rest in 63. After surgery eight patients were pain free while stress pain occurred in 35 and rest pain in 35 ($P < 0.01$). As assessed by the patient the condition had improved in 51 cases, remained unchanged in 18 and had been impaired in 10. Bone union ensued in less than 2 months in 12 patients, in 2-4 months in 37 and within more than 4 months in 8 cases. Two cases failed to unite. The results in the group of patients under 20 years of age were better than in the remainder ($P < 0.05$). Those in whom bone union took less than 4 months achieved better results ($P < 0.001$) than those with a longer bone union time.

EARLY RECONSTRUCTION OF THE BRACHIAL PLEXUS AFTER BIRTH INJURIES

A. A. Solonen, S. Ryyppö & T. Talaranta
Orthopaedic Hospital of the Invalid Foundation, Helsinki

Two infants, 8 and 12 weeks of age, had extensive lesions of the brachial plexus. The indication for surgery was based upon clinical and electromyographic findings showing cessation of recovery. In the first case roots C5, C6 and C7 were reconstructed with free grafts. In the second case only root C5 could be reconstructed. No motor function was lost and it is highly unlikely that function of the deltoid and biceps muscles would have recovered without reconstruction.

Analysis Group already existing in Odense, to survey the actual pattern of injuries

were found to have good results at examination

THE INTERFASCICULAR TRANSPLANTATION TECHNIQUE IN THE TREATMENT OF INJURIES OF THE MEDIAN NERVE

K Simesen, J Haase & P Bjerre

Department of Neurosurgery, Odense Hospital

Twenty-four patients were operated upon, in a 3-year period, for complete median nerve transection using the microsurgical interfascicular transplantation technique. The patients were re-examined after a minimum observation time of 3 years. Motor function (M3 or higher) was achieved by 83 per cent. With the exception of one patient, all achieved protective tactile sensibility. The best results were obtained in distal lesions in children and youths. The outcome was just as satisfactory as that attained with epineurial suture carried out under ideal conditions. The method was found to be superior to epineurial end-to-end suture in cases of nerve defects longer than 2.5 cm.

"HOME-MADE" SILICONE RUBBER IMPLANTS IN THE CARPUS

J Hedeboe

Department of Orthopaedic Surgery, Hospital

The history, indications and the replacement of the navicular or base of the carpus by silicone rubber implants are discussed.

Eight patients operated on since 1975 presented. The prosthesis was cut and the Silastic block by the surgeon.

Seven patients were able to return to work. None have been reoperated on during the follow-up period (mean 4 years). Complications: wear and dislocation of the implant or neighbouring bones can occur with commercially produced prostheses, so it is an advantage to be able to make the implant individually.

ASEPTIC PROCEDURES IN ORTHOPAEDIC SURGERY

J Krogh Christoffersen et al.

Department of Orthopaedic Surgery, Hospital

In a central operating unit serving different surgical departments, special procedures are necessary. Access to the theatre is through a specially designed complete covering of the hall. Operating coats are made to cover the trousers are tucked into special boots. Pairs of gloves are worn.

During operations where bone cement is used the doors in the operating theatre are closed from the inside. The skin is painted with antiseptic and covered with Steridrape. Suction is connected to a closed suction system. The possibility of retrograde contamination of the procedure. 405 consecutive total hip replacement operations have been performed with one case of infection.

THE INTERFASCICULAR TRANSPLANTATION TECHNIQUE IN THE TREATMENT OF FINGER NERVE LESIONS

K Simesen & J Haase

Department of Neurosurgery, Odense Hospital

Thirty-two patients with 39 finger nerve lesions were treated by microsurgical interfascicular transplantation. They were followed up after a minimum of 2 years (mean 39 months).

Protective sensibility was achieved by 90 per cent. Almost normal two-point discrimination sensibility was found in children and youths. The results were better than those obtained by epineurial suture carried out under ideal conditions.

In two-thirds of the cases the operation was undertaken because of pain and two-thirds of these

MEETINGS OF FINNISH ORTHOPAEDIC ASSOCIATION

Tampere, Finland, March 10, 1979

A ALHO

ULTRASONIC CUTTING OF BONE

H Kallioniemi, A J Aho & P Lehtinen
City Hospital,
Department of Oral Surgery, Institute of
Dentistry, University of Turku,
Department of Surgery, Turku University Central
Hospital, Department of Electron Microscopy, University of

sonic cutting of bone has been reported to
have some advantages (accuracy, decreased
cutting space, smooth bone edge) over con-
tinuous oscillating and rotatory cutting. The
aim of the present study was to determine
the immediate effects on bone and periosteum
of an ultrasonic saw (URSK-7,
Ultrasonic, USA) differed from those of an oscillating saw.

Surfaces of rabbit ulnar and scapular bone
osteotomy were prepared, immediately after
cutting, for scanning electron microscopic (SEM)
histological studies.

It is easier to control the osteotomy line by
ultrasonic cutting, whereas the cutting speed of
the oscillating saw was greater than that of the
ultrasonic saw. Histologically the differences were
small and the amount of thermal necrosis of the
bone was equal and independent of saline cooling.
Observations revealed that the ultrasonic
cutting produced rather rough surfaces and the periosteum
tended to become elevated. Osteotomies made by
the oscillating saw showed some microfractures
and parallel grooves, but the surfaces were flatter,
and the edge of the periosteum was not affected as
it was by an ultrasonic saw.

BILATERAL SPINE FUSION AND ANALYSIS OF THREE CONSECUTIVE CASES

Ilkka P Salenius, P Pylkkanen & P

Department of Surgery, Turku University Central
Hospital, Department of Electron Microscopy, University of

During the period 1972-1976, 37 women and
43 men were treated surgically. Their mean age
was 30 years. The indications for surgery were
spondylolysis and spondylolisthesis in 73 cases,
and instability in seven. One vertebral interval
was fused in 60 cases and several fused in 20. The
period spent in bed after surgery was usually 2-4
weeks (44 patients). A questionnaire was sent to
the patients between 1 and 5 years after surgery.

Pain was recorded before surgery at stress in all
patients, and at rest in 63. After surgery eight
patients were pain-free, while stress pain occurred
in 69 and rest pain in 35 ($P < 0.01$). As assessed
by the patient, the condition had improved in 51
cases, remained unchanged in 18 and had been
impaired in 10. Bone union ensued in less than 2
months in 12 patients, in 2-4 months in 57, and
within more than 4 months in 8 cases, two cases
failed to unite. The results in the group of patients
under 20 years of age were better than in the
remainder ($P < 0.05$). Those in whom bone union
took less than 4 months achieved better results
($P < 0.001$) than those with a longer bone union
time.

EARLY RECONSTRUCTION OF THE BRACHIAL PLEXUS AFTER BIRTH INJURIES

K A Solonen, S Rjöppö & T Telaranta
Orthopaedic Hospital of the Invalid Foundation,
Helsinki

Two infants, 8 and 12 weeks of age, had
extensive lesions of the brachial plexus. The in-
dication for surgery was based upon clinical and
electromyographic findings showing cessation of
recovery. In the first case roots C5, C6 and C7
were reconstructed with free grafts. In the second
case only root C5 could be reconstructed. No
motor function was lost, and it is highly unlikely
that function of the deltoid and biceps muscles
would have recovered without reconstruction.

RUPTURE OF THE DISTAL BICEPS BRACHII TENDON

M V Vastamäki & H M Brummer

Loimaa Regional Hospital, Loimaa,

Orthopaedic Hospital of the Invalid Foundation, Helsinki

Five cases of rupture of the distal biceps brachii insertion were operated on using the technique described by Thomsen in 1939. The mean age of the patients was 50 years.

In each case the trauma mechanism was a sudden extension of a previously flexed elbow with a snapping sensation or sound, soreness and weakness, proximal bulging with distal flatness of the arm, and the inability to flex the elbow or supinate the forearm completely. The avulsed tendon was reinserted into its attachment at the radial tuberosity using two approaches. Three cases operated on in the early stage after injury recovered completely. The other two patients, operated on 1 and 3 years after the injury, had slight weakness of elbow movement. The average follow-up time was 3 years.

RECURRENT LUXATION AND OSTEOARTHRITIS OF THE MANDIBULAR CONDYLE TREATED BY CLOSED CONDYLOTOMY AND COSTOCHONDRAL GRAFT

Ari Tasanen

Maxillofacial Unit, Helsinki University Central Hospital

A total of 586 closed condylotomies were performed for minor disorders of the temporomandibular joint, such as mild osteoarthritis, joint luxation and mandibular prognathism.

Thirty-five arthroplasties were performed using a costochondral graft for the treatment of more serious joint derangements. This method was used in post-traumatic joint ankylosis, severe osteoarthritis, rheumatoid arthritis, bony ankylosis and osteomyelitis.

One patient suffered from habitual luxation in one mandibular joint, and from severe arthrosis in the opposite joint, resulting in malocclusion of the teeth, facial deformity, headache and joint pain for 13 years. A closed condylotomy was performed on one joint for treatment of recurrent luxation. On the opposite side a new joint was constructed using an autologous costochondral graft. In the follow-up both mandibular joints functioned well, pain was relieved and the facial appearance restored to normal.

THE ACUTE EFFECTS OF ARTICULAR AGENTS ON ARTICULAR CARTILAGE IN RABBITS UNDER GOING STRENUOUS EXERCISE

A U Artola, S Santorini & T S

Division of Experimental Medicine, I

of Cellular Biology, University of Jyväskylä

Division of Orthopaedic Surgery

Traumatology, Surgical Hospital, Helsinki Central Hospital

Department of Pathology, University of Jyväskylä

The present study was designed to examine the acute effects of intra-articular steroid (GAGPS) injections on the articular cartilage in healthy rabbits under strenuous exercise. The controls were treated with intra-muscular GAGPS or saline. Twenty-two rabbits were subjected to strenuous loading of the knee joint down from 1.5 m over a 10-day period. The animals were killed on the tenth day. The articular cartilage of the medial femoral condyle was examined using light and scanning electron microscopy. This preliminary study showed extensive morphological changes in the articular cartilage of the rabbits after repeated jumping over a period of 10 days. The most marked pathological changes were found in the articular cartilage of the rabbits treated intra-articularly with saline. Intra-articular betametasone and GAGPS intra-muscular GAGPS seemed to have a beneficial protective effect on the articular cartilage. Further experiments must be done in order to clarify the inhibiting effects of corticosteroids on

VASCULAR PEDICLE FREE BONY TRANSPLANTATION

A A Solonen & T Telenius

Orthopaedic Hospital of the Invalid Foundation, Helsinki

A free fibular graft with a vascular pedicle was used in three cases. In all cases the artery and vein in the transplant were anastomosed to end with appropriate vessels.

The distal radius of a 44-year-old patient had been replaced by a free non-vascularized graft 7 years earlier because of a haemangioma. Fracture of the radius resulted in non-union. We performed an extensive excision of the hypoplastic

The defect with a vascularized free fibular transfer was performed on a 42 year-old woman who had undergone three unsuccessful attempts at correction of a deformed talocrural joint. A 23-year-old woman had had three unsuccessful attempts at achieving ankylosis of a dislocated hip joint. An attempt was made to arthrodesis the joint with a free vascularized fibular graft. The results are promising.

LEG LENGTHENING BY THE OSTEOTOMY METHOD

by
J. University Central Hospital

This series consists of three cases with congenital malformation and severe shortening of the lower extremities. In the first case, congenital hypoplasia, fused congenital talocrural joints and hemimelic epiphyseal arrest. An epiphyseodesis of the longer leg had been performed earlier in two cases. The patients were 11, 13 and 14 years old at the time of lengthening was performed. The lengthening was transverse in two cases and a long oblique osteotomy with a periosteal sheath in the third case. The Wagner apparatus was used in the first two cases. In one case a severe rotation and varus deformity, and in another a severe rotation deformity corrected simultaneously. The amount of lengthening was 3.5, 3.7 and 8.5 cm and the length discrepancy 1.5, 1.5 and 0 cm, respectively. Bone transplantation and plate fixation were performed in the first two cases after

the lengthening was completed. The oblique osteotomy fused spontaneously. The Achilles tendon was lengthened in all cases. There were no infections, no cases with delayed union, nerve or vascular damage. The time from the beginning of the lengthening to full weight-bearing was 4-6 months.

It is concluded that the method is useful in equalizing severe leg length discrepancy and can be used to complement epiphyseodesis. It allows simultaneous correction of axial and rotational deformities. Various associated problems must be coped with depending on the other pathological features of the short extremity.

USE OF 70 MM FLUOROGRAPHY IN DIAGNOSING ORTHOPAEDIC PROBLEMS

U. Lahdenranta & H. Linden

Department of Orthopaedics and Traumatology and Department of Radiology of the Surgical Hospital, Helsinki University Central Hospital

In three cases a dynamic illustration of pathologic movements documenting the various phases, was obtained by means of a 70 mm spot film series. In the first case the stages involved in the subluxation of the shoulder joint were specified. In the second case, the movement of a pseudarthrosis close to the elbow joint was visualized, and at the same time the movement of the elbow joint was documented both preoperatively and postoperatively after union of the pseudarthrosis. In the third case, the minimal movement arising from retarded ossification of the proximal part of the tibia, close to an osteoarthrotic and unstable knee was traced with the aid of a spot-film series.

MEETINGS OF

NORWEGIAN ORTHOPAEDIC ASSOCIATION

ARNT JAKOBSEN

January 27th, 1979

ULNAR SYNOVECTOMY OF THE WRIST IN RHEUMATOID ARTHRITIS

Pahle

Sanitetsforening Rheumatism Hospital, Oslo

In the period 1967-1978, 776 synovectomies were performed for rheumatoid arthritis of the wrist. Of these, only 17 later on required an arthroplasty.

The operation included a full tenosynovectomy of the extensor tendons, excision of the ulnar head of the triangular disc, as well as a thorough ulnar and radiocarpal arthrosynovectomy. The pisiform joint is opened on the ulnar side. The extensor carpi ulnaris tendon is in a good position. In this position, this important muscle function is maintained by transfer of the extensor radialis in order to prevent radial deviation of the wrist. Division of the intercarpal ligaments gives easy access to the volar erosions of the carpal

repositioning is not achieved, and the patient shows signs of myelopathy, laminectomy and lateral fixation with bone cement are carried out. Four such operations have been performed.

RESECTION ARTHROPLASTY OF THE FOREFOOT IN RHEUMATOID ARTHRITIS

Tore Ottesen

Oslo Sanitetsforening Rheumatism Hospital, Oslo

A detailed account of a modified Clayton technique was presented. During the past year the 1st metatarsal-phalangeal joint has been replaced by a Swanson silastic prosthesis with promising results.

PATIENT INFORMATION - LOW BACK PAIN

Tore K Kvien

Hospital of Rheumatology, Kristiansand

Is there possibly a difference in the information given to patients with low back pain by group and traditional physiotherapy?

A total of 220 patients were instructed in self training, mainly in the form of isometric exercises and correct ergonomic use of the back. Instruction was given to small groups of patients with the aid of 12 diastape lessons over a period of 4 weeks. A physiotherapist demonstrated the exercises and answered questions.

Another 190 patients were treated traditionally (controls).

One year later the patients were asked to fill in a questionnaire. The group-instructed patients had received significantly less physiotherapy than the patients treated traditionally during that year. Ninety-five per cent of the group treated patients, and about 50 per cent of the control patients, considered that the information was communicated satisfactorily.

DISLOCATION OF THE CERVICAL SPINE IN RHEUMATOID ARTHRITIS

Englund

Sanitetsforening Rheumatism Hospital, Oslo

In the period 1975-1978, 35 patients with forward dislocation of the cervical spine and neurological symptoms were operated on at the Brattstrom/Granholm. If the deviation was less than 10 mm and myelopathy was not present, the patients were treated conservatively with a supporting collar.

In patients with downward dislocation, a ventral operation for transoral removal of the odontoid process.

In patients with backward dislocation and paraplegia was treated with operative reduction and fixation with bone cement.

In subaxial dislocations with major deviations, an attempt at repositioning is made, and when successful, a frontal fixation is performed. In patients with a modified Cloward method. If

SEROLOGY IN RHEUMATOID ARTHRITIS

Ove J Melbye

Institute of Immunology & Rheumatology, The National Hospital, Oslo

A short review of serology in rheumatoid arthritis was presented. It was recommended that the latex test be used initially, and, if this is positive, then a Waaler-Rose test can be performed. The anti-nuclear immunofluorescence test is recommended for initial testing of anti-nuclear antibodies.

Oslo, March 10th, 1979

TUMOURS OF THE TIBIA

Emor Wollébaek

Central Hospital in Vestfold, Tønsberg

Two patients with tumours with an almost identical location in the medial condyle of the tibia were presented. The diameter of the tumours was 5 cm, and the findings at radiological examination suggested both to be malignant.

One case turned out to be a metastasis from a carcinoma of the kidney, and the primary tumour was not found until 5 years later. In the second case the tumour was benign. It contained mostly cholesterol although the patient did not present any other signs of hypercholesterolaemia.

Trondheim, May 25th-26th, 1979

SICK LEAVE AMONG SOCCER PLAYERS AND IN THE POPULATION

Aibjorn Roaas & Gunnar Andersson

Martina Hansens Hospital, Sandvika and Sahlgrenska Sjukhuset, Göteborg

One hundred previously active or still active soccer players, aged 30-40 years, were compared with 108 age-matched controls selected to represent the male population of the city of Göteborg. Sick listing was compared between the two groups based on the sick leave register. There was no difference in the total number of days on sick leave. Infectious diseases were responsible for about 55 per cent of the total number of sick days in both groups. Among the soccer players 77 per cent had been on sick leave because of injuries to the lower extremities and 73 per cent because of other injuries. In the control group these figures were 48 per cent and 49 per cent, respectively. Other diseases of various types were more frequent among the controls.

FRACTURE OF THE INTERCONDYLAR EMINENCE OF THE TIBIA

August Bakke, Anders Møller & Ole Lunde
Regional Hospital Bergen

Fracture of the intercondylar eminence of the tibia is a rather rare fracture. In the period 1970-1978 14 patients with this fracture were treated conservatively.

At the follow up examination the result of the patients was excellent. Of the five had a good result and in one the result was fair.

It is concluded that childhood fractures I and II (according to Meyers & Allread) should be immobilized in a cast for 3 weeks and that type III requires open reduction and internal fixation. In older patients type II should be operatively treated.

ARTHROSCOPY OF THE KNEE JOINT: A COMPARISON OF THE FINDINGS IN ARTHROSCOPY, ARTHROGRAPHY AND ARTHROTOMY

Pål Benum

Regional Hospital Trondheim

The findings of arthroscopy and arthrotomy were compared in 60 "chronic" knees. Arthroscopy failed to diagnose 2 of 20 meniscus lesions found at arthrotomy. Furthermore, 1 out of 3 retained posterior horns were overlooked. One false positive anterior meniscus lesion was made in arthroscopy. Arthroscopy failed to diagnose 1 out of 10 of the anterior cruciate ligament lesions and 1 rupture of the posterior cruciate ligament. In arthrotomy. Cartilage lesions were found in 10 knees only in 2 knees were the lesions recognized at arthroscopy.

Compared with arthrotomy, arthroscopy was found to be far superior as regards the detection of meniscus lesions.

These findings, and a comparison of clinical diagnosis, led to the conclusion that arthroscopy is very valuable in the diagnosis of chronic knee problems.

SOFT TISSUE TUMOURS IN THE POPLITEAL FOSSA

Peter A. Groh

Regional Hospital, Trondheim

In a 4-year period 23 cysts and 7 soft tissue neoplasms were seen in the popliteal fossa.

in adults mainly symptomatically in connection with knee joint diseases. In children it is decided that the operation be delayed until the cysts disappear spontaneously in 60 per cent of cases. Neoplasms in the popliteal fossa are classified

COMPARISON OF INTERNAL FIXATION AND PROSTHETIC REPLACEMENT FOR FEMORAL NECK FRACTURES

Olav Nasse
Hospital, Trondheim

A prospective study of 216 patients with intracapsular femoral neck fractures is reported. 109 patients were treated by primary fixation using a Christiansen endoprosthesis, and 107 patients by internal fixation with a nail-plate. The rate of complications, non-union, and the mortality rate, were no different between the two groups. The results of the prosthesis group compared with the results of the nail-plate group are as follows:

Internal fixation group. It is concluded that in patients above 70 years a primary prosthesis is to be preferred.

RESULTS OF THE NECK OF THE

The preliminary results of a prospective study concerning subcapital fractures of the femur are reported.

Forty patients were treated according to the method of compression screw osteosynthesis, and compared with 47 patients treated with McLaughlin's nail-plate. Immediate weight-bearing was allowed. The mean observation time was 6 months. In the group with displaced fractures no difference was found between the two methods (all healed). In the group with undisplaced fractures, however, 30 out of 32 treated with compression screw osteosynthesis were healed after 6 months, compared with only 16 out of 47 treated with the nail-plate.

It is concluded that in displaced subcapital fractures of the neck of the femur the compression screw method used gives faster results than the McLaughlin nail-plate method.

COMPRESSION HIP SCREW IN

The preliminary report involves 40 fractures in 25 women and 14 men with an average age 61.9 years. The Garden grades were: grade II - 3 hips, grade III - 20 hips, and grade IV - 17 hips. The fractures were fixed using a sliding compression screw plate.

At the follow-up (average 1 year) three cases showed avascular necrosis of varying degree and two had non-union. In one patient total hip replacement was performed after a technical failure and in another a Girdlestone operation was necessary because of infection.

Sliding of the screw varied from 10 to 14 mm in six cases, from 4 to 9 mm in five cases and from 0 to 3 mm in the remainder. The preliminary results compare favourably with an earlier series where two or three separate screws were used. The results will be compared with preliminary hemiprosthesis replacement in a randomized series.

HALLUX RIGIDUS TREATED WITH SWANSON'S SILASTIC HEMI-JOINT PROSTHESIS

Anders Molster, Ole D. Lunde & Milan Rast
Coastal Hospital in Hagevik, Hagevik

The results of 25 operations performed between 1972 and 1978, substituting the proximal part of the phalanx with a silastic prosthesis, are reported.

Twenty patients (21 operated joints) appeared for re-examination, the rest answered a questionnaire. The mean observation time was 47 months. One prosthesis was removed because of deep infection and one because of trauma. Patients' opinion: Excellent in 16, good in 6, fair in 2 and poor in one. Objective assessment: Excellent in 8, good in 9 (one with prosthesis removed), fair in 3 and poor in one (with prosthesis removed).

Most patients had limitation of mobility, but normal walking ability. Strength was well preserved, and only one patient complained of marked pain. Radiologically there were some signs of bone reaction to the prosthesis.

Anton Hole, Terje Terjesen & Harald Brerøth
Regional Hospital, Trondheim

A prospective, randomized study of 60 elderly patients undergoing total hip arthroplasty was carried out. Modified neurolept anaesthesia with manual ventilation was compared with single dose bupivacaine 0.75 per cent epidural analgesia. Blood loss perioperatively was less in the epidural group. PaO_2 was reduced in the general anaesthesia group on the 1st and 3rd postoperative days ($P < 0.01$) compared both with preoperative values and with the epidural group. No patients in the epidural group, but seven patients in the general anaesthesia group, developed mental changes postoperatively ($P < 0.01$). One patient in the general anaesthesia group died from acute myocardial infarction. The patients were equally satisfied with both types of anaesthesia.

HALO-VEST IMMOBILIZATION OF UNSTABLE INJURIES OF THE CERVICAL SPINE

Tor Steinar Raugstad
Regional Hospital, Bergen

Ordinary skull traction usually prevents dislocation of a cervical spine injury, but the patient is confined to bed and the method does not effectively restrict movements of the head and neck.

The halo-vest equipment gives a better stability than any other orthoses made for external immobilization of the cervical spine. A metal ring is fixed to the skull by special screws or pins, and a vest of plastic material that fits over the shoulders and the chest is connected by adjustable rods. This allows the patient to be ambulatory, and a long period in bed can be avoided.

Seven patients with unstable cervical injuries have been treated by this method with good results.

ACCURACY IN SKELETAL AGE ASSESSMENT

Lars B. Skogland & Morten Eek
Sophies Minde Orthopaedic Hospital, Oslo

The skeletal age of 30 girls, 7 to 17 years old, was estimated four times each by two observers, using the Greulich and Pyle method. About 2

weeks passed between each reading. The value of the first reading of both observers was called the "true skeletal age".

Checking the reliability (reproducibility) of the method, it was found that approximately the readings were distributed within ± 1 year of the "true skeletal age". If ± 1.2 years were chosen as an acceptable margin, 95 per cent of the readings would have been included.

The objectivity (interobserver) difference was also estimated. Whereas the mean of the three control readings of observer A was distributed above the "true skeletal age", the corresponding readings of observer B were distributed below it. This was the case in 29 out of 30 observations, and in one case the difference between the two was as much as 1½ years.

It is probably advisable that the skeletal age be estimated by at least two observers, and a high degree of accuracy is required.

FRACTURE OF THE NECK OF THE TALUS

Rolf Hagen
Martina Hansens Hospital, Sandvika

Talar fractures are rare and occur in motor vehicle and athletic accidents, in heights and in injuries caused by falling. The most common type is fracture of the neck which constitutes 50 per cent. The talar body dislocation implies in most cases one or three main sources of the blood supply.

Two cases with closed fractures of the Hawkins group III are reported. In the first primary pantalar arthrodesis was performed. In the second case an open fracture in a 58 year-old man while an open fracture of the tibia. Internal fixation was done in a three-jumper within 2½ hours of the accident.

PERIPHERAL NERVE INJURIES FOLLOWING TOTAL HIP REPLACEMENT

Ludvig Fjeld Solheim & Rolf Hagen
Martina Hansens Hospital, Sandvika

Six nerve complications after total hip replacements by the posterior approach are reported.

Peroperatively the sciatic nerve was injured directly in one patient, and in one patient the femoral and two patients with sciatic nerve the nerves were probably stretched or crushed by retractors. Postoperatively one patient had a haematoma in the buttock with sciatic

and one patient an iliacus haematoma
 dorsal nerve paralysis
 Patients were treated conservatively, in one
 and two femoral nerve lesions the patients
 normal function, while in three sciatic
 lesions there were residual neural deficits

ANTERIOR OSTEOTOMY IN THE TREATMENT OF INCREASED CERVICAL NECK ANTEVERSION A PROSPECTIVE STUDY J. Henningsen St. Olav Hospital, Trondheim

A difference of opinion prevails about the in-
 dication for operative treatment of increased
 cervical neck anteversion, and the optimal age for
 operation. Furthermore, it is questionable
 whether or not the anteversion will recur after the
 operation.
 To investigate some of these problems a pro-
 spective study has been started in children who
 show signs of increased anteversion, measuring
 the anteversion angle prior to, and at intervals after,
 a high tibial derotation osteotomy using the
 Derotation method.
 The material consists of 60 patients, mean age
 8 years. A quarter of the patients were known to

have hip dysplasia, and three-quarters had isolated
 increased anteversion. At follow-up 4 and 12
 months postoperatively there seems to be no
 recurrence of the anteversion.

The study will be continued.

STABILIZATION OF THE DISTAL ULNA FOLLOWING RESECTION

Norvald Langeland

Sophies Minde Orthopaedic Hospital, Oslo

Following resection of the distal ulna according
 to Darrach the stump may sometimes become so
 mobile that it causes pain and damage in the
 forearm. A new method for stabilizing this
 hypermobile distal ulnar stump is described.

The extensor indicis proprius tendon is divided
 at the second metacarpo-phalangeal joint. The
 tendon is withdrawn to above the wrist, and
 looped around the radius from the dorsal to the
 volar side, hereupon it is taken dorsal to and
 around the ulna to the volar side of both ulna and
 radius. Finally the tendon is looped around the
 radius to its dorsal side where it is sutured to
 itself.

This "dynamic" method has been found to
 stabilize the ulna effectively.

MEETINGS OF THE SWEDISH ORTHOPAEDIC ASSOCIATION

June 6-10, 1979

PETER HERBERTS

TREATMENT OF DIAPHYSEAL FRACTURES OF THE UPPER EXTREMITY WITH FUNCTIONAL BRACES

Enskog, J. Enskog & J. Karlsson
Department of Orthopaedic Surgery, Umeå

In closed diaphyseal fractures of the upper extremity we were treated with a tight orthoplastic brace in a very short acute stage. The median age was 33 years (range 16-82), the fracture site was at various levels of the shaft, and often comminuted. The median time required for healing without pain, callus) was 10 weeks (range, 6-18). After an observation time of 11 months (range, 5-23) 11 patients were symptom-free and 2 had minor symptoms at examination, while 2 had minor symptoms.

In 2 ulnar and 2 radial diaphyseal fractures were treated, after the swelling had subsided, with a tightly fitting brace. Thus the distance from the wrist to near the elbow was the same for all patients. The time required for healing was 11 weeks (range, 5-27), and 11 out of 15 patients returned to work for a median period of 12 weeks (range, 0-28). The results were good (symptom-free) in 13 and acceptable in 2 cases.

TREATMENT OF DIAPHYSEAL FRACTURES OF THE LOWER EXTREMITY WITH FUNCTIONAL BRACES

Enskog, J. Enskog & J. Karlsson
Department of Orthopaedic Surgery, Umeå

In an initial stage in traction (median 6 weeks, range, 2-10), 21 transverse, longitudinal or oblique fractures of the distal two-thirds of the femur were treated in a functional cast brace. The median age was 40 years (range, 16-78). Three fractures were open. The median total hospitalization was 8 weeks (range 4-15) and the median time 16 weeks (range, 10-26). The results

were good in 15 cases, acceptable in 3 and poor in 2 cases. No pseudoarthrosis occurred.

Sixty-two fractures of the tibial shaft were treated in a functional brace after an initial period in a long leg cast. Median age was 36 years (range 16-78) and 12 fractures were open. Only six were the result of skiing injuries. Six of the fractures were fixed with screws for only 4-8 weeks. Thirty-four cases braced within 6 weeks

Results: Good 47, acceptable 9 and poor 5 cases. In 4 of these the reason was delayed union and after bone grafting they all healed with a final good result.

Selected material was 18 weeks (range, 6-88). Results: Good 47, acceptable 9 and poor 5 cases. In 4 of these the reason was delayed union and after bone grafting they all healed with a final good result.

SEMI-RIGID FIXATION OF DISTAL FEMORAL FRACTURES BY A NEW DEVICE

L. Kolmert & B. M. Persson
Department of Orthopaedic Surgery, Lund University Hospital, Lund

Distal femoral fractures, especially supracondylar and bicondylar, are often difficult to treat. An 8-year analysis in Malmö and Lund showed that in one-third of 137 fractures the result was fair or poor. Forty-six of the fractures were operatively treated and there was no difference between these and the conservatively treated ones.

A prospective series was started in 1978. A semi-rigid type of fixation was devised, composed of Ender nails of various sizes, cancellous screws and a metal piece to connect the Ender nail with the screws. An anterior plaster was used postoperatively for 2 weeks and then most of the patients used a cast-brace. The semi-rigid fixation can maintain a good position despite bone fragility and has made it possible to mobilize the patients earlier.

FEMORAL NECK FRACTURE AND OCCULT EPISODIC CARDIAC ARRHYTHMIA

N-J Abdon & B Nilsson

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Sixty consecutive patients admitted to hospital for fracture of the upper end of the femur were examined by continuous ECG monitoring for 24 hours. More than one-third of the patients had occult, previously undiscovered, episodes of arrhythmia, severe enough to cause cerebral symptoms.

This prevalence is much higher than in an age-matched sample of the population at risk.

ACUTE TOTAL HIP ARTHROPLASTY FOR PROXIMAL FEMORAL FRACTURE IN PATIENTS WITH OSTEOARTHRITIS OF THE HIPS

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Coxarthrosis and hip fracture are both common in the elderly but the combination is seldom seen. In 236 cases of cervical hip fracture, Ståhl (1957) did not find any case of simultaneous coxarthrosis but in 50 trochanteric fractures 20 had some degree of coxarthrosis. From medicine we found one case reported by Ganz (1978) of total hip operation for fracture and arthrosis. In Lund, 1969 to 1979, we have found the following six cases:

Case	Age	Sex	Hip disease	Fracture	Operation
1	73	M	Bechterew	Cervical	McKee-Parrar
2	56	M	CDH + OA	Subtroch	Charnley Long
3	89	F	Bj OA	Pertroch	Brunswick
4	70	F	III OA	Pertroch	Lubinus
5	80	F	OA + Myeloma	Subtroch	Charnley Long
6	76	M	Bj OA	Pertroch	Lubinus

In three cases the proximal fragment was resected, in three cases it was preserved. Early weight-bearing was possible and all operations were successful. Acute total hip is indicated in severe coxarthrosis also after fracture.

POSTOPERATIVE WOUND INFECTION IN CLEAN ORTHOPAEDIC OPERATIONS

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A prospective study of 2371 clean orthopaedic operations revealed 3.7 per cent postoperative

wound infections. Fourteen factors related to the aetiology of postoperative infection were subjected in a computer. Multiple linear-regression analysis was used. Only three factors were found to be significant in determining the development of wound sepsis. These were the age of the patient, the use of allografts and the use of antibiotics.

The diagnostic criteria and suitable methods for registering postoperative wound infections are discussed.

EFFECTS OF PROTECTIVE CLOTHING ON AIRBORNE CONTAMINATION WITH BACTERIA AND PARTICLES IN A LAMINAR CROSS-FLOW OPERATING ROOM

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The effect of different types of protective clothing on the transmission of bacteria and particles was studied during sham operations in a cross-flow operating unit.

No differences in bacterial or particle counts were found comparing a helmet, a face mask and a nonsterile head-clothing connect to a possible hood of the square type and triple laminar face masks. In both cases the number of bacteria and particles were low. Experiments without any covering of the head resulted in a major increase in bacterial counts without a corresponding increase in the number of particles.

Disposable operating gowns of Tyvek or woven rayon yielded similar numbers of bacteria and particles. Conventional non-sterile gowns increased both the number of bacteria and the number of particles. The "wound" infection rate recorded with cotton gowns was about 75 per cent with the use of both disposable gowns.

POSTOPERATIVE INFECTION RATE - EFFECT OF CLEAN AIR CROSS-FLOW UNIT AND RIGID HYGIENE ROOM

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During the period 1970 to 1979 a total of 1000 hips were replaced by a total prostheses.

Operations were performed in a conventional operating theatre using cotton gowns. During the years 1977-1978, 176 prosthetic replacements of knees were performed in a clean air unit with laminar air flow. The surgical team used disposable gowns of non-woven rayon, square type and triple laminar face masks. The clean air reduced the superficial infection rate from 6.9 per cent ($P < 0.02$) and the deep infections from 3 to 0 per cent ($P < 0.02$). In our previous publications we have shown an infection rate of 5-15 per cent after surgery for cervical and intertrochanteric femoral fractures. To evaluate the effect of the rigid hygiene routines at the clinic for cervical, 55 trochanteric femoral fractures were studied prospectively and retrospectively. Operations were performed in a conventional operating theatre using cotton gowns. The infection rate was 0.9 per cent.

ROLE OF HAMSTRING TENDON RELEASE IN THE MANAGEMENT OF KNEE FLEXION DEFORMITY IN CEREBROLOGICAL DISEASE

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During the years 1967-1978, 31 patients with cerebral palsy or myelomeningocele were operated for knee flexion deformity. Twenty-eight patients (31 knees) were followed up. Mean age 11 years, average follow-up period 5 years. Indication for operation was a true hamstring contracture causing a knee flexion deformity. In 7 patients Eggers' original technique was used. In the remaining 21 knees it was modified individually. No major vascular complications or deep infections occurred. Of 13 non-functional walkers, 10 were able to walk after operation. Of 9 independent walkers 8 became community walkers. No walking capacity was lost because of the operation. The contracture decreased in all operated knees. No significant differences could be observed between patients with cerebral palsy and myelomeningocele. All but 2 of the 28 patients were subjectively improved. No recurrence of deformity was observed despite an average follow-up of 5 years. A weakening of the flexion power of the knee was observed in most cases, but did not interfere with function. The results suggest that distal hamstring tendon release can be recommended in the management of true knee flexion deformity in cerebral palsy and in myelomeningocele.

GROWTH DISTURBANCE AFTER ANKLE FRACTURES IN CHILDREN

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In a prospective study of ankle fractures in children, the effects on longitudinal growth were registered by insertion of $\frac{1}{2}$ mm sized tantalum balls. The patients were followed up with X-ray stereophotogrammetry at regular intervals. Measurements on 20 patients have been made. Eleven of the patients had a growth retardation. Thus a higher frequency than earlier reported and the Salter-Harris classification seemed to be of lesser value in predicting the prognosis. The growth disturbance could now be registered some months after the injury and with great accuracy. Growth disturbance after ankle fractures results in clinical problems in a few cases, and early diagnosis is important for future therapy.

GROWTH ARREST BY STAPLING AND EPIPHYSIODESIS

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The orthopaedic surgeon often encounters the problem of leg length discrepancy. We have found operative growth arrest, temporary or permanent, more valuable than leg shortening, lengthening or growth stimulation. Preoperative planning is of critical importance. If this is not properly carried out, then even with excellent surgical technique and a careful follow-up the end result can be disappointing. In order to study the effect of growth arrest after stapling and epiphysiodesis and to evaluate the early signs of problems, a rontgen stereophotogrammetric analysis was performed. Thirty stapling operations according to Blount and seven Phenister operations were studied.

Conclusion: Rontgen stereophotogrammetry is suitable for checking the efficiency of staples and growth arrest after Phenister epiphysiodesis.

Stapling during the latter part of the growth period results in immediate and complete growth

arrest. Removal of staples results in normal growth in intact growth plates and normal closure. Phenister epiphysiodesis results in immediate and complete growth arrest.

GROWTH DISTURBANCE AFTER INJURY TO GROWTH PLATES OF THE DISTAL FEMUR AND PROXIMAL TIBIA STUDIED BY ROENTGEN STEREOPHOTOGRAMMETRY

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There has been a great deal of interest in the classification of physical injuries in order to predict growth disturbances. A roentgen stereophotogrammetric analysis of 5 cases was used to study the growth disturbance after injuries to the growth plates of the distal femur (Salter-

distal femur. In the type IV injury to the proximal tibia there was asymmetrical growth.

Conclusion

1. The roentgen stereophotogrammetric method proved useful in determining the growth rate after physical injury.

2. The Salter-Harris classification is of minor value in predicting growth disturbance.

3. Physical injuries must be treated with meticulous care to secure intact growth and congruity of the joint.

4. The leg length discrepancy or angular deformity can be determined, facilitating pre-operative planning.

EARLY ASSESSMENT OF PROGNOSIS IN PERTHES' DISEASE

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The principles of treatment in Perthes' disease are rather confusing. This is caused among other things by the difficulties in making an early

to early risk evaluation. An index that takes account of changes in the proximal femur as well as in the pelvis has been devised. This index also seems to correlate well with the radiological end-result in the early phase of the disease.

HETEROLOGOUS BONE GRAFT TRANSPLANT IN INNOMINATE OSTEOTOMY FOR HIP DYSPLASIA

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A heterologous bone graft, Kjelholz, was used in 10 cases of innominate osteotomy of the pelvis for treatment of hip dysplasia. Two main advantages with this graft: 1. It is not necessary to take a crista bone graft which is followed by disturbed growth of the distal femur due to the apophysis. The second advantage is that large grafts can be obtained which in re-osteotomies must be used in order to correct the deformity. Hitherto in all cases the graft has been incorporated without any loss of correction or collapse of the transplant.

EXPERIENCES WITH THE SHARRARD POSTERIOR ILIOPSOAS TRANSFER IN MYELOMENINGOCELE

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A follow-up study was made of the posterior iliopectus transfer in myelomeningocele patients with hip instability or verified luxation or subluxation. The study comprised 19 hips in 12 patients. The mean age at operation was 2.5 years, range 14 months to 4 years. Postoperative follow-up ranged from 1 to 10 years, mean 4.4 years. The technique described by Sharrard. The results of those reported by other authors. A stable hip result was defined as a stable hip in a reduced position. Nine of the 19 hips were reduced and 10 dislocated postoperatively. Intertrochanteric femoral fracture, 3 cases; femoral fractures and 2 cases of avascular necrosis of the femoral head were observed postoperatively. The position of the hip prior to surgery was of importance. Of 7 totally dislocated hips, 3 retained their position in the reduced position postoperatively. Of 12 subluxated hips, 8 were stable at follow-up. This indicates that posterior iliopectus transfer is not a good method for the treatment of the hip in children with subluxated hips.

CENTRE PROSPECTIVE OF SWEDISH KNEE IMPLANTATIONS

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October 1975, SOF started the "Swedish
arthroplasty Project" involving 38
hospitals. In April 1979, 3,070
operations were registered and 1,573 of these
had a 1 year follow-up. Results at follow-up
for the main diagnoses, RA and OA

At present semi-constrained prostheses are
more often used than constrained. Total surface
replacement in RA is more often done with
bicondylar than unicondylar prostheses resulting
in less subluxation and infection, the same rate of
loosening but in more patellar problems. In OA
only 1 per cent of the demiplasties have needed
secondary arthroplasty of the non-operated com-
partment and these have given the best overall
results. In RA, demiplasties have led to 7 per cent
reoperations because of further arthritic destruc-
tion.

Diagnosis	Rheumatoid arthritis (n = 734)			Osteoarthritis (n = 722)		
	No	Complic	Total/Infect./Loose	No	Complic	Total/Infect./Loose
Uncon-	164		12% 5% 3%	71		24% 9% 11%
Con-	237		10% 2% 3%	129		16% 4% 6%
total	274		10% 3% 3%	73		10% 2% 2%
demiplast	59		17% ~ 2%	449		7% 1% 2%

SECONDARY OPERATIONS AFTER JOINT ARTHROPLASTY

Lin & A. Ahlberg
Department of Orthopaedic Surgery, Malmö
Hospital, Malmö

A total of 267 knee joint arthroplasties were
performed in 1972-1977 and 31 required
secondary operations, which means a frequency of
11.6 per cent. In the rheumatoid group the
frequency was 6 per cent, in osteoarthritis 18 per
cent. Loosening was the reason for the reoperation
in 15 cases and infection in 7. Hinge prostheses
required reoperation more often than the other
types (Geomedic, III & George Schlittenprothese).
Earlier and earlier operation in the same knee
increased the risk of complications leading to
revision. The type of reoperation was exchange
of prosthesis in 17, arthrodesis in 3, amputation
in 3, femur amputation in one. The
reasons for 7 were various smaller interventions.
The cause of the reoperations was classified as
follows: 13 cases, fair in 12 and poor in 6.

TECHNIQUE FOR UNICONDYLAR ARTHROPLASTY

Linstrand & G. Thor-Jönsson
Department of Orthopedics, Lund

Positioning of the tibial and the femoral
components is accomplished by using a special
instrument. In the proximal tibia we
perform an L-resection. With the aid of the guide
instrument this is done horizontally in both the

transversal and sagittal planes. The tibial
component covers the strong cortical bone and its
stability is enhanced by cement-pegs down into
cortical bone. The femoral component is also
positioned with the guide instrument, this ensures
correct placement and good congruity between the
two components. In a fixed deformity it is important
to transpose the collateral ligament in order to
obtain a correct valgus position of the leg. The
collateral ligament is anchored with a special
ligament staple. The guide instrument and the
ligament staple were demonstrated.

TWO UNUSUAL AND SEVERE COMPLICATIONS IN KNEE ARTHROPLASTY

A. Wigren, K. Kolstad & B. Sahlgren
University Hospital, Uppsala

Two knee arthroplasties with unexpected com-
plications are described.

The first case was a combination of sciatic
nerve injury and a compartmental syndrome of the
lower leg. The patient had severe rheumatic
arthritis of other knees. This deformity was

corrected by tenotomy of the ischaemia initiating the com-
partmental syndrome was caused by arterial
spasm due to tension when the flexion deformity
was corrected.

The second case was a fracture of the proximal
tibia close to a bone-cemented giant rheumatic

granuloma upon which the Marmor knee prosthesis had been placed. One year after the primary operation the cortical and cancellous bone close to the cement was necrotic. There was no infection and bone necrosis was the cause of the fracture. It is suggested that special types of prostheses, custom-made if necessary, should be used in cases where bone cement otherwise would be used in large amounts to fill a bone defect.

MARMOR KNEE ARTHROPLASTY STUDIED BY ISOMETRIC AND ISOKINETIC MUSCLE STRENGTH MEASUREMENTS

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University Hospital, Uppsala

A prospective study was made of the knee muscle strength of 40 knee joints fitted with a Marmor knee arthroplasty. Twenty-five of the knees were in RA patients, 15 in cases with OA. Isometric strength measurements of knee extension and flexion were performed preoperatively and at 3, 12 and 24 months postoperatively. The preoperative isometric strength in RA was only 10-25 per cent of that in a normal material. The corresponding values for OA were 30-50 per cent. The maximal isometric muscle strength in RA was significantly increased both for flexion and extension 1 and 2 years postoperatively and for flexion at 3 months postoperatively. No significant increase was seen in OA. The increase in knee flexion strength was earlier and more pronounced than that of knee extension in both groups. This indicates the necessity of extension training postoperatively to prevent flexion deformity. Further information for analysis of knee pain and for interpretation of functional observations after knee surgery was given by the use of isokinetic muscle strength studies with the Cybex II apparatus. Knee extension strength at high speed increased significantly explaining the normalized gait after arthroplasty even if isometric values were unchanged.

ANALGESIC DISC PUNCTURE DIAGNOSTIC DISC PUNCTURE DETERMINING THE LEVEL FOR SPINAL FUSION IN PATIENTS WITH CHRONIC LOW-BACK PAIN

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Since August 1977 twelve patients with chronic low-back pain and a normal myelogram have been

evaluated with analgesic lumbar disc puncture.

particular level. An average of three tests were performed in each patient.

Seven patients have been operated on and obtained good results and have returned to their former occupation. Though the experience with this new method so far is small, the results are promising and the method warrants a larger series.

WORKING IN LOGGING MACHINERY C Hammar Skogshälsan, Boden

Eighteen per cent of logging machine operators complain of cervical pain which is not significantly different from that of other forestry employees. Earlier unrestricted work of lumbermen may have contributed to the high rate. The rate of cervical trouble is decreasing in the fifties and sixties is still too small to draw conclusions. Experience gained by the occupational health service shows that machine drivers complain to a greater extent of the neck, shoulders and arms. The trunk and compartment are not yet considered to minimize health hazards. This is a matter considering that plans are being made to expand machinery resources and more complicated and exacting demands. It is of importance in this context to consider the ergonomic demands to reduce the physical demands than to be only concerned with the profitability of the machines.

EXPERIENCES OF AUTO-TRACTOR ON SCIATICA S Ingeborg Department of Orthopaedic Surgery

Forty-six patients with clinical signs of vertebral disc herniation were selected from our clinic's waiting list. The mean age was 40 years. The history of dorsal pain was 1-20 years and all of them had been treated previously by various methods of treatment without success. Vertebroplasty was performed in 9 cases and 7 of these patients had a herniation of the lumbar disc. No manifestations were found in 17 patients. These were treated with a McKenzie manoeuvre to reduce the herniation. The results were repeated depending upon the disc

the symptoms, and the mean was 4.5 in each patient

its were classified as *very good* in 22

urological symptoms occurred in 12

ury, 43 out of 46 patients with chronic

vously treated without satisfactory

re treated successfully with Auto-

IC NEEDLE

COPY OF THE KNEE

CAL ANAESTHESIA

Buring, T Wikström & J Ekstrand
of Orthopaedic Surgery, Sundsvall

October 1977 polichinc needle

Results of the first 200 are reported

amination in the case of suspected

scopy The number of arthrographies

radically reduced during this period

of the arthroscopies was around 90

here have not been any infections or

ications We believe the method is safe

high accuracy As this is an outpatient

done in a consultation room the

the regular operation ward is reduced

methods to increase the diagnostic

cartilage while the staining of normal

as minimal. The methylene blue

was compared with corresponding

and scanning electron microscopic

The degree of staining seemed to be

he depth of the cartilage lesion More

lesions of the cartilage had a greater

he dye than superficial lesions.

al dose for clinical use was 20 mg

blue dissolved in 40 ml of saline

Subcutaneous injections of methylene blue have been reported to produce necrosis In order to prevent this possibility the intraarticular injection should be made through the arthroscope

CLINICAL AND ARTHROGRAPHIC

RESULTS OF CONVENTIONAL

BAKER CYST EXCISIONS

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Uppsala

Forty-one cases were reviewed 6 months to 15 years (mean 4 years) postoperatively. At all operations the cysts had been radically excised and the communication had been closed in 25 cases. 15 major complications were encountered in the early postoperative course in 13 patients. 9 wound healing disturbances with fever necessitated a total of 6 wound revisions. In 6 cases "deep venous thrombosis" of the calf was diagnosed. At the clinical follow-up 63 per cent of the cysts had recurred. Arthrography revealed as many as 40 recurrent cysts. It is concluded that the majority of operations had been performed on the basis of indications which were too broad. Failure to close the communication tightly is believed to account for the recurrences as well as for the postoperative complications, as synovial fluid pumped out of the joint is known to have tissue-irritating properties.

LATE EFFECTS OF PATELLECTOMY

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Hospital, Eskilstuna

Twenty-two patellectomies performed during 1973-1975 were examined clinically and the muscle strength was registered by the CYBEX II apparatus. Three-quarters of the patients were satisfied with the operation essentially because of lack of pain at rest. However, at the clinical examination only 8/22 (36 per cent) of the patients were considered to have good results.

The disadvantages of patellectomy were found to be residual pain on walking, reduced muscle strength and instability with the knee in extension. The average loss of muscle strength (recorded by the CYBEX II apparatus) was more than 50 per cent - isometric as well as isokinetic - as compared with the contralateral leg.

DRILLING OF OSTEOCHONDRITIS DISSECANS LESIONS IN KNEE JOINTS

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Sclerosis in the subchondral bone of adult knee joints with osteochondritis dissecans is an effective barrier to healing. It has to be destroyed to stimulate healing of the bone with the rest of the condyle. A method of subchondral drilling from the side of the condyle against the lesion, without interfering with the articular cartilage, was studied. Twelve adult patients were operated on. Four lesions were mobile and eight immobile. Three were treated with plaster, and two of them were also pinned with bone pegs. At the follow-up examination 34–53 months later, eight lesions were healed on the radiograms. These patients had no symptoms. Four lesions had not healed and these patients had pain. In two of these knees the lesions had loosened and were later removed. There was no significant difference between healed or unhealed lesions as regards sex, preoperative duration, age, postoperative duration, mobility or site of the lesion.

PROGNOSIS IN PRIMARY SHOULDER DISLOCATION: A PRELIMINARY REPORT OF A PROSPECTIVE MULTICENTER STUDY

L. Hovelius, J. Weckström, K. Eriksson, J. Thorling, B. Lind, H. Fredin, G. Hagberg & F. Kylberg

The treatment of primary shoulder dislocation in young people is a controversial subject. The literature is briefly reviewed and information is given on a prospective multicenter study involving 25 large and small Swedish hospitals. Primary shoulder dislocations in persons 40 years or younger, have, since January 1978, been treated either by early mobilization (1–2 weeks in mitella) or immobilization with the arm bandaged to the body (3–4 weeks). Up to the beginning of May 1979, 174 shoulder dislocations had been treated of which 79 belong to the first and 95 to the second group. Sixteen have been treated such that they cannot be placed in either of the two groups. The collecting of the material will continue through 1979 and the total material will be followed up during 1981.

RECURRENT POSTERIOR LUXATION OF THE SHOULDER JOINT—DIAGNOSTIC MANAGEMENT AND THERAPY IN SEVEN CASES

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Seven cases of recurrent posterior luxation of the shoulder joint have been treated. The result of trauma and frequency of occurrence.

Neurovascular symptoms, not previously, with paraesthesia in the arm in six out of seven cases. The luxation appeared in six cases stabilized by a glenoplasty according to Scott. In the posterior Putti-Platt vascular and nerve tests should be performed in all primary diagnosis.

A new roentgenographic technique which is of great value preoperatively in estimating the degree of posterior dislocation as well as compression fractures of the cavitas glenoidalis and the capsular method has also been used to check the osteotomy of the collum scapulae after transplantation.

Overall good results were seen in the study 6 months–3.5 years postoperatively.

THROMBOEMBOLISM AFTER ELECTIVE AND POST-TRAUMATIC HIP SURGERY—A CONTROLLED PROPHYLACTIC TRIAL WITH DEXTRAN AND LOW DOSE HEPARIN

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A prospective randomized controlled trial has been undertaken to evaluate two prophylactic treatments against postoperative thromboembolic complications after hip surgery. Patients with hip fracture (77) and undergoing elective hip arthroplasty (127) were separately randomized into one of two groups: control dextran 70 or low-dose heparin. Venous thrombosis was diagnosed with venous thrombography, and pulmonary embolism with the fibrinogen test, and pulmonary embolism in the arthroplasty group with a contrast-enhanced pulmonary angiogram. The frequency of thrombosis was higher in untreated hip fracture patients than in untreated arthroplasty patients. In both treatments a significant reduction in the frequency of thrombosis was seen.

transversoplanus) was not significantly increased

In summary, it is obvious that these patients have many problems. Further technical and clinical development of total ankle replacement seems to be necessary.

ACCEPTANCE OF MYOELECTRIC HAND PROSTHESES AMONG UNILATERAL BELOW-ELBOW AMPUTEES

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In order to determine the acceptance and usefulness of myoelectric prostheses for unilateral below-elbow amputees 38 patients supplied with such devices were followed up with the aid of an extensive questionnaire. All patients using their prostheses were personally interviewed and tested for ADL performance with their prostheses. In a group of 16 patients the application of the prosthesis was supervised by a specialized team consisting of an orthopaedic surgeon, an occupational therapist, and an orthopaedic technician. The team met the patients at regular intervals during the first year, and was responsible for information training and follow up. Another group of 22 patients obtained their prosthesis through orthopaedic surgeons with no special interest in hand prosthetics.

The acceptance in the group of trained patients was 56 per cent and in the untrained group 23 per cent. It is concluded that acceptance of myoelectric hand prostheses in unilateral below-elbow amputees is significantly increased through adequate training and follow-up during the first year after the application of the prosthesis.

THE DIAGNOSIS AND TREATMENT OF ACUTE HEMATOGENOUS OSTEOMYELITIS (AHO)

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Three cases are presented in whom there were no initial radiological findings. In one patient the radiogram was normal even 2 weeks after the onset of symptoms despite a large lesion in the proximal metaphysis of the humerus. In one case also Technetium phosphate scanning was normal. Bone scanning may be negative in AHO during the first week (Garrett et al 1977, *Brit J Radiol* 50, 757). An extremely tender, localized area of bone was in all instances the earliest sign of AHO. (The thumb of the surgeon is an instru-

ment available even under the poorest conditions.) Pain, fever and distinct tenderness are symptoms and signs which contribute to the diagnosis. We also suggest that decompression may be necessary in the early progression including secondary abscesses observed in spite of adequate intravenous antibiotics given within 24 hours.

CONSERVATIVE TREATMENT OF AMPUTATED FINGERS

S. Holmner & P. Magnusson
Department of Surgery, Boden

A method for conservative treatment of fingertip and finger amputation, using zinc adhesive tape as an occlusion device, is presented. Forty-three patients ranging in age from 15 to 73 years have been treated in this way since 1975. Exposure of bone was recorded in 12 cases. No attempt was made to cover the bone with the tape. The tape was applied directly on the wound and a bandage was then changed daily during the first 3 days and as healing proceeded the time between changes was extended to up to 3-4 days. The treatment was completed within 3-5 weeks. All patients were followed up and the end results. Sensibility remained almost normal. The cosmetic appearance of the healed finger was acceptable and normal. The method is easy, cheap and gives good end results.

FOOT DEFORMITIES IN CHILDREN: A METHOD FOR SIMPLE EXAMINATION AND DOCUMENTATION

B. Romanus

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Foot deformities in children are easily recognized in such terms as varus, valgus, adduction, etc., and graded as mild, moderate or severe. This classification is based on the clinical examination and prevents continuous evaluation of the deformity of the feet and any effect of treatment. Objective methods for documentation are necessary. Pictures or photographs are time-consuming and demand standardized projectors and cameras. A quick and simple method is to draw the contours of the feet in sanding with a marker on paper or plastic sheet. The drawings are reproducible and are good as documents. By superimposing the drawings of both feet on a grid of millimeters, by comparing different drawings

ld's feet it is easy to see and measure in size because of growth, unilateral es, effects of treatment etc

REPLACEMENT IN TOTAL, COMPLETELY REPLACED HIP

B L Unander-Scharin
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one hips in 17 patients, all women, operated upon mainly by a method by Harris. Pain has in every case been indication for operation. Postoperative results: bone length has been maintained in most cases but Trendelenburg's sign remained positive. Walking range has improved and most patients walk without pain. Postoperative evaluation: improvement in 19/21 patients in 2/21. There is definitely an improvement in this operation but the comparatively should be centralized.

RADIATION DOSES IN ORTHOPAEDIC SURGERY

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A study of the radiation exposure of personnel has been made during 23 operations for pertrochanteric and femoral neck fractures. The reduction as well as the insertion of Ender nails and von Bahr screws were with the aid of fluoroscopy.

Doses of 4 mR/operation or more were registered only for the surgeons. Measurements on the surgeons' hands gave a mean value of 25 mR/operation with a maximal dose of 154 mR. Registration of the radiation dose close to the eyes gave values of 4-27 mR (mean 13 mR). The radiation dose/year for the eyes and hands might for some of the surgeons well exceed the stipulated maximal doses.

Thus, it is most important that the safety regulations are strictly followed, that the surgeon is aware of the risks, that protective glasses are always used and that the video disc recorder is used whenever possible. With these precautions the radiation doses will be reduced by 80-90 per cent.

to the Editor

r,

letter to the Editor, Dr Bohr (Bohr 1973) had been incorrectly cited in all of the 13 cases Bohr had found, irrespective of the stage of Perthes' disease, increased radiological

In the 10 cases he examined radiographically he found all had areas of increased activity in the affected capital femoral epiphysis. One "early condensation" showed only a "little uptake" and four "condensation" cases showed "somewhat increased" activity in the lateral part of the epiphysis. The main conclusion he drew from his observations was that the sclerosis was due to revascularization and appositional bone formation.

It is therefore reasonable to cite, in our discussion of the cause of the radiological changes, that "Bohr (1973) found increased activity in the initial stage and supported

the opinion that the increased density was due to appositional bone formation" (Fasting et al 1978).

Perhaps we should also have cited from his work in our paragraph on the diagnostic value of the reduced uptake on scintigrams. However we found Bohr's results difficult to interpret as far as the diagnosis of Perthes' disease is concerned.

Ove J Fasting M D

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Announcement

Fourth International Conference on Ski Trauma and Ski Safety, June 7-12, 1981
Bormio, Italian Alps

Among the topics for discussion

Biomechanics of ski lesions

Prevention and treatment of ski injuries

For further information please contact

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Announcement

BOA — NOF — NOV Amsterdam 1980

The joint congress of the British Dutch and Nordic Orthopaedic Associations will be held in Amsterdam on October 1-3, 1980. The congress programme includes free papers, round table discussions and poster sessions.

A second announcement in May will contain the major items on the programme. Contributions to the poster sessions should be submitted before August 1, 1980.

Members may obtain detailed information from the congress secretariat

c/o Organisatie Bureau Amsterdam BV

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1078 GZ Amsterdam, The Netherlands

NOPHILIC GRANULOMA OF BONE

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Forty-three patients with histologically proven Histiocytosis X localized to bone at presentation have been reviewed. Thirty-six patients presented with solitary bone lesions and 31 have healed without complication with a mean follow-up of 10 years. The remaining five patients developed polyostotic disease, three exhibiting either pulmonary lesions or diabetes insipidus. Seven patients presented with multiple bone lesions and six of them developed other bone lesions. Four of these patients also showed some of the features of Hand-Schüller-Christian disease. An increase in size of the presenting bone lesion within a few months of biopsy heralded the subsequent development of further bone or soft tissue lesions and was the only feature of prognostic value.

Keywords: eosinophilic granuloma, Histiocytosis X

Accepted 16 xi 79

phalic granuloma is a destructive lesion and represents the localized station of Histiocytosis X (Lichtenstein 1953, 1964). Hand-Schüller-Christian is the chronic disseminated form characterized by progressive bone lesions, endocrine involvement and sometimes, diabetes insipidus and exophthalmos. The prognosis is uncertain and spontaneous remission may occur. Letterer-Siwe disease is the illness in young children characterized by the presence of widespread, predominantly visceral lesions and carries a poor prognosis (Cheyne 1971). Although most solitary bone lesions have been reported to heal with or without treatment, the subsequent appearance of further bone lesions or progression to the chronic disseminated form has been described (Oberman 1961, Harris & Francis 1961, Fowles & Hinko 1970, Cheyne 1971, Schajowicz & Mel 1973). On the basis of their own observations Oschner (1966) and McGavran (1960) challenged this latter proposition.

The purpose of this presentation is to analyse the features that may indicate which lesions initially confined to bone may be complicated by the development of further bone or soft tissue lesions. The effects of radiotherapy on the healing of long bone lesions and the neurological complications of vertebral body disease are also discussed.

PATIENTS

The clinical records, radiographs and pathological findings of 43 patients seen at the Nuffield Orthopaedic Centre, or referred to the Bristol Bone Tumour Registry since 1945, were reviewed. All had histologically proven Histiocytosis X localized to bone at presentation. Patients with soft tissue lesions evident at the time of presentation were excluded. Twenty-six patients had solitary bone lesions. A skeletal survey was performed in 24 of these patients at presentation. Five developed other bone lesions. Seven patients presented with multiple skeletal lesions and six of them developed

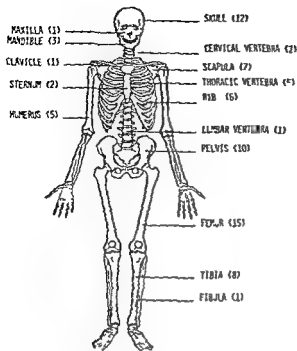


Figure 1 The sites of 79 bone lesions in 43 patients

further bone lesions. The sites of the skeletal lesions are shown in Figure 1

The mean age at presentation of 43 patients was 17 years 9 months (range 1 year 6 months to 64 years). The mean age at follow up of 38 patients was 34 years (range 6 years to 60 years) the average period of follow-up being 10 years (Figure 2). Five patients died due to progression of the disease at a mean time of 3 years following diagnosis.

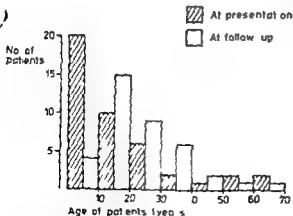


Figure 2 Histogram showing the age distribution of 43 patients at presentation and 38 patients at follow-up. Five patients died

Radiology

The radiological features of some of the patients in this series have been reported previously (et al 1973) and agree with other series (e.g. 1966 Takahashi et al 1966). In long bone lesions the lesion appears as an irregular, lytic area in the medulla, usually with endosteal erosion. Cortical destruction may be evident (Fig. 3) there may be an "onion skin" periosteal reaction in diaphyseal lesions. Marginal sclerosis is not considered to have healed in these patients. The trabecular pattern had returned to normal when the lytic area had been totally replaced by a localized area of sclerosis. Flat bones have irregular lytic areas. Either complete healing may occur upon healing or the lesion may remain though with a well defined margin.

Histology

In all patients, the diagnosis of Histiocytosis was confirmed by histological examination. The essential histological features are well known (Lichtenstein 1964 Price 1971). Characteristic histological appearance is of collections of



Figure 3 Patient 1 Table 1. Lateral view of proximal femur showing a large lytic lesion with cortical destruction in a 13-year-old patient presented with a 1 month history of pain in right hip

phs always accompanied by histiocytes h lymphocytes and sometimes plasma cells ion. Multinuclear giant cells of osteoclast occasionally present but never in large a. In Hand Schuller-Christian disease the s composed predominantly of histiocytes are sometimes lipid-containing and the uils are scanty Fibroblastic differentiation observed in lesions of both eosinophilic na and Hand Schuller-Christian disease considered as evidence of healing However f fibrosis may be seen in lesions which - to enlarge after biopsy

the patients who died were over the age of 50 at diagnosis and the presence of progressive bone lesions in this age group would seem to carry a bad prognosis In contrast, four of the five children who had widely disseminated bone disease survived though after a prolonged period of illness

Sequential X rays or detailed clinical records of the presenting bone lesions were

NATURAL HISTORY AND TREATMENT

Long bone lesions

six patients presented with solitary sions and 31 healed with no adverse e The minimum period of follow-up 3 months The lesions were treated by excision biopsy, or by incision

long bone lesions following incision and curettage has been assessed by using serial radiographs in twelve s treated with or without radiotherapy ean time to healing of the five lesions with radiotherapy was 12 months and seven lesions treated with curettage was 11 months.

Multiple bone lesions

patients presented with solitary bone but developed polyostotic disease. patients presented with multiple bone and six of these developed further sions The clinical details are shown in 1 Of these twelve patients seven pro- 1 to the Hand Schuller Christian me Five patients had pulmonary in- vent which appeared late in the disease 10 of these had diabetes insipidus. All patients have died Two patients had diabetes insipidus alone Four of



Figure 4 Patient 12 Table 1 Antero-posterior X ray of the distal left tibia in a male aged 58 years showing an irregular lytic lesion in the medulla with endosteal erosion prior to biopsy

Table 1 The clinical details of 12 patients who had multiple skeletal lesions first presented to hospital

Patient	Age at presentation (years)	Symptomatic bone lesion at presentation	Asymptomatic lesions present on skeletal survey	Tissue
1	12	Proximal femoral metaphysis	8th dorsal vertebra	Exposed bone
2	3	Skull Occiput	None	Exposed Ribs
3	2½	Ilium (Left)	None	Exposed Ribs
4	1½	Skull	Rib Femora	Exposed Ribs of skull
5	4½	4th dorsal vertebra	None	None
6	2½	Ilium Skull	None	Exposed Ribs
7	1½	Skull (proptosis)	None	Exposed Ribs
8	26	Acromium	None	Exposed Ribs
9	61	Mandible Rib	None	Exposed
10	54	Femur (pathological fracture)	Left 6th rib	Exposed Fracture of femur
11	64	Skull Sternum Scapula	None	Exposed Ribs
12	58	Tibia (left)	Tibia (right) Ilium	Exposed Ribs

Age of patient at presentation	Timing and site of subsequent bone lesions	Complications	Age and status at follow-up
lesion neck	None	None	14 years Healed lesion femoral neck
lesion	2 years - base of skull	Diabetes insipidus	14 years No further bone lesions
lesion in size	12 months - ilium (right) 34 months - humerus 39 months - skull	None	21 years Normal
lesion on	11 months - tibia	None	18 years - Normal
lesion cut	9 months - tibia (biopsy taken) Widespread vertebral lesions	None	17 years - Normal
lesion in size	7 months - skull, occiput 11 months - skull, parietal 14 months - scapula, cervical spine 19 months - humerus, ilium	None	29 years Normal
lesion in size on	12 months - skull, ilium Later - scapula, femora	None	4 years - Died, disseminated disease
lesion in size on	11 months - 2nd lumbar vertebra Followed shortly by multiple vertebra	Paraplegia	28 years - Died, disseminated disease
lesion in size on at	9 months - femora, tibiae, pelvis 12 months - skull	Diabetes insipidus	62 years - Died, disseminated disease
lesion on	6 months - 5th, 6th, 7th, 8th, 9th dorsal vertebrae	Diabetes insipidus Paraplegia	59 years Died, disseminated disease
lesion in size all lesion	7 months - 6th cervical vertebra 3 years - 2nd, 4th and 5th cervical vertebrae	Tetraparesis	68 years - Died, disseminated disease
lesion in size on	8 months - bone scan showed generalized lesions	Diabetes insipidus	60 years - Progressive bone lesions

available for study in eight of the eleven patients who developed further bone or soft tissue lesions. In all cases the primary lesion was noted to increase in size following biopsy and curettage (Figures 4, 5, 6, 7, 8, 9). There

was no increase in size of the primary lesion in the one patient (Patient 17) who when reviewed at 2 years had developed further skeletal lesions. The therapy did not appear to control the



Figure 5 Patient 12 Table 1 At 5 months after biopsy, there is an increase in size of the lesion noted, despite external radiotherapy. Again the proximal tibia is radiologically normal. A repeat bone scan demonstrated multiple skeletal deposits.



Figure 6 Patient 12 Table 1 At 20 months after biopsy, the left tibia at 20 months shows a widespread medullary lesion involving the proximal and distal tibia.



7 Patient 8 Table 1 An X ray of the humerus in a male aged 26 years showing a lytic lesion.

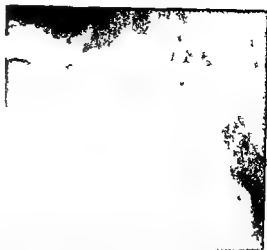


Figure 9 Patient 8 Table 1 X ray of the acromium 5 months after biopsy showing increased destruction despite external radiotherapy. Multiple vertebral lesions were now evident.



8 Patient 8 Table 1 X ray of the humerus 2 months after biopsy showing partial healing.

lesions were all multiple (Figure 10) and were complicated by severe spinal cord damage. The three adult patients died. One of the five children had multiple dorso-lumbar lesions (Figure 11) and four solitary lesions. There were no neurological complications and healing of the vertebral lesions occurred.

DISCUSSION

This review of 43 patients with Histiocytosis X confirms that most solitary bone lesions heal without complication. However five of the thirty six patients with solitary lesions at presentation and six of the seven patients with multiple lesions at presentation developed other bone lesions. Seven of these eleven patients with progressive disease later developed either diabetes insipidus or pulmonary involvement. A feature of prognostic significance was an increase in size of the presenting skeletal lesion following biopsy and curettage which heralded the appearance of other bone or soft tissue lesions. Fowles & Bobechko (1970) described this occurrence in two of the forty four children in their series. Although Cheyne (1971) has described one

tion and did not prevent the subsequent appearance of further bone lesions.

neurological complications of vertebral

the adults and five children had additional body lesions. In the former the

available for study in eight of the eleven patients who developed further bone or soft tissue lesions. In all cases the primary lesion was noted to increase in size following biopsy and curettage (Figures 4, 5, 6, 7, 8, 9). There

was no increase in size of the primary lesion in the one patient (Patient 10) who when reviewed at 2 years had developed further skeletal metastases. Therapy did not appear to correlate



Figure 5 Patient 12 Table 1 At 5 months after biopsy there is an increase in size of the lesion noted despite external radiotherapy. Again the proximal tibia is radiologically normal. A repeat bone scan demonstrated multiple skeletal deposits.



Figure 6 Patient 12 Table 1 At 20 months after the left tibia at 20 months there is widespread medullary lesions over the proximal and distal tibia.

ACKNOWLEDGEMENTS

I am grateful to Dr C G Woods, Consultant Pathologist, Nuffield Orthopaedic Centre, who has offered continual help and encouragement. I would like to thank Dr N G Sanerkin for allowing me to review the records of patients referred to the Bristol Bone Tumour Registry and the Consultant Staff at the Nuffield Orthopaedic Centre for allowing me to review their patients. I would also like to thank Dr J L Boldero for allowing access to his X-ray collections.

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Fig 11 Patient 5 Table 1 Lateral X-ray of cervical spine in a girl aged 11 years showing evidence of multiple vertebral bodies. There were neurological complications.

of vertebral lesions (Oberman 1961, Lichtenstein 1966, Cheyne 1971) Neurological deterioration and death may supervene. The treatment of vertebral lesions should be conservative initially with bracing as far as possible. In many series, the lesions were treated with radiotherapy (500-1,000 rad) and later healed. Needle or open biopsy should be performed as positive histology is essential for diagnosis. Operative treatment should be required for those lesions with neurological complications.

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THE BONE MARROW CELL CONTENT AND OSTEOCLASTS IN CRISTA BIOPSIES

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The bone marrow cell content was investigated by counting the percentage of cells in the areas between the trabeculae in crista biopsies. There was a decrease in the percentage of cells in bone marrow in osteoporotic women compared with our normal material. In patients undergoing haemodialysis there was a positive correlation between bone marrow cell content and osteoclasts, which could indicate a possible connection between osteoclasts and bone marrow cells.

Key words: bone biopsy, bone marrow cells, bone volume, osteoclasts

Accepted 9 VII 79

It has earlier been discussed by Owen (1978) that haematogenic cells could be involved in bone resorption. Burkhardt (1977) has studied the importance of bone marrow and its vascularization in the development of osteoporosis. Bone marrow content in different types of bone diseases has also been investigated (de Velde et al. 1977). We have studied bone marrow response after trauma, finding an increase in the number of cells in bone marrow after experimental fractures in rats. At the same time we found an increased number of osteoclasts in the ribs (Johnell & Hulth 1977, Hulth & Johnell 1976).

MATERIAL AND METHODS

Bone marrow samples from the iliac crest were taken from three different groups of patients: 23 osteoporotic women, 14 alcoholics and 15 patients undergoing haemodialysis. Normal autopsy material was obtained from 12 women and 24 men at the Institute of Pathology. All these people had died suddenly after cardiac arrest, accident or suicide. Biopsies were taken using a Burkhardt instrumentarium (Burkhardt 1966) from the top

of the iliac crest, 2 to 3 cm behind the iliac spine. The biopsies were embedded in methylmethacrylate and sectioned undecalcified into sections 4 to 7 µm in size. The sections were

falling on bone trabeculae on bone marrow on cells and on bone marrow without cells, respectively, were counted. The percentage of bone marrow cells was determined by dividing the number of intersections falling on cells in the bone marrow by the total number of intersections counted in bone marrow $\times 100$. In the haemodialysis group the percentage of intersections on sites of osteitis fibrosa of the total bone marrow was counted in the same way. The number of osteoclasts was counted according to the system described earlier (Johnell et al. 1977). In the osteoporotic group bone mass in the radius and ulna at 1 and 5 cm from the distal end of the ulna was determined by gamma absorptiometry with Americium 291 (Nilsson & Westlin 1972).

RESULTS

In our normal material we found no difference between men and women, no correlation between age and percentage of cells

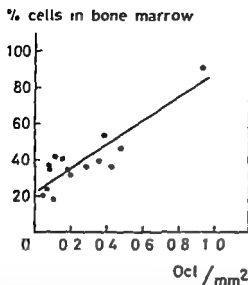


Figure 1 A positive correlation between the number of osteoclasts/mm² and the percentage of cells in bone marrow of 15 haemodialysis patients ($r=0.88$)

in bone marrow, and only a weak correlation between the number of osteoclasts and the percentage of cells in bone marrow. This can be explained by the small span in the number of osteoclasts in this group. By contrast in the haemodialysis group, we found a positive correlation between osteoclasts and the percentage of cells (Figure 1). There was no such correlation in the alcoholic and osteoporotic groups. The average number of bone marrow cells was higher in the normal

group than in the osteoporotic group and Student's *t*-test was significant (Table 1). There was no difference in age in these groups. In the osteoporotic group we also found a positive correlation between osteoclasts and the bone mass at 1 cm level on the radius ($r=0.50$), but no such correlation at 6 cm. (In the normal material obtained

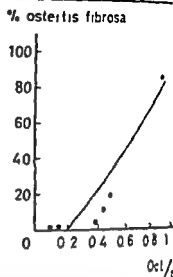


Figure 2 A positive correlation between the number of osteoclasts/mm² and the percentage of osteitis fibrosa in the bone marrow of 15 haemodialysis patients ($r=0.93$)

from the Forensic Department densitometric measurements were made). There was also a positive correlation between the number of osteoclasts and the percentage of osteitis fibrosa in the haemodialysis group (Figure 2). Osteitis fibrosa was found in all the 15 haemodialysis patients.

DISCUSSION

There seems to be a correlation between the number of osteoclasts and the percentage of osteitis fibrosa in the haemodialysis group. This is an indirect connection between the number of osteoclasts and the development of osteitis fibrosa, as discussed by Owen (1978). It was interesting to find that the number of

Table 1 Comparison between the number of bone marrow cells in the normal and osteoporotic groups

	Number	% cells in bone marrow	<i>t</i> -test
Normals	12	$48.7 \pm 14.5 (\pm \text{s.d.})$	$3.95 P < 0.001$
Osteoporotics	25	$30.7 \pm 8.9 (\pm \text{s.d.})$	

the marrow of osteoporotic women was significantly lower than that of women in the control group, and this could indicate an increase in the bone tissue in the osteoporotic women. As we have described earlier there was an increase in osteoid surface and the number of osteoclasts was low in the patients with osteoporosis.

The correlation between osteoclasts and bone mass was at the 1 cm level but not at 6 cm. This can be explained by the fact that the number of osteoclasts was calculated from the number of osteoclasts in the iliac crest and at the 1 cm level on the radius, where the majority of the bone tissue is trabecular, at 6 cm the majority is cortical.

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SKIN REACTION AND METAL SENSITIVITY

Animal Study

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An animal study is presented in which nickel sensitivity as determined by an *in vitro* test for leukocyte migration inhibition (LIF) is correlated with results of skin tests with NiCl_2 and with the degree of adverse tissue reaction to implanted stainless steel screws. Screws were implanted in the humeri of New Zealand white rabbits, one group of which received repeated injections of nickel chloride following an initial injection of nickel chloride in Freund's adjuvant. All the injected rabbits became skin test positive to nickel and demonstrated LIF production in the presence of nickel chloride. Some of the injected rabbits, 6-9 weeks after implantation of the screws, developed an inability for leukocyte migration even when the cells were incubated only with saline and serum. The tissue reaction to

condition of no leukocyte migration in the LIF test. The correlation between skin test and LIF test results demonstrates the effectiveness of the LIF assay for sensitivity testing without the risk of sensitization associated with skin testing. The histological results support the hypothesis that the condition of no cell migration in the LIF test is diagnostic for severe reactions to implants associated with metal sensitivity.

Key words: implant, LIF, nickel, rabbit, screw, sensitivity

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role of metal sensitivity in complications associated with the use of metallic implants is still a matter of debate. The increasing use of metallic implants has led to increased discussion. Some patients with a metal sensitivity have been demonstrated to have increased morbidity following the use of various internal metallic devices including wires, clips, screws, nails, rods, and joint arthroplasties (Sancroft & Solomon 1972, Benson et al 1976a, Brown et al 1976a, Cramers & Lucht 1975, Evans et al 1974, Merritt et al 1979). However, the contribution of this metal sensitivity to such complications is still con-

troversial, whether or not and for how long sensitive individuals can accept metal appliances is still open to question. Some claim there is no problem (Fisher 1973, 1977), while others will deviate from their usual implant material selection so as to avoid implanting appliances with one or more metal alloy constituents to which the patient is sensitive (Deutman et al 1977). Certainly sensitivity is not the cause of all problems, although in some cases it may be a major factor.

In order to study the incidence of metal sensitivity in orthopaedic patients, without

the risk of sensitization associated with repeated skin testing (Meneghini & Angelini 1977) we have developed an *in vitro* test for metal sensitivity (Brown et al 1976b Merritt et al 1979a, 1979b). The leukocyte migration inhibition (LIF) test method was selected because of the known association between the presence of cell mediated immunity and the production of lymphokines such as LIF *in vitro* (Rocklin & David 1976). Ameboid leukocytes such as macrophages and polymorphonuclear leukocytes will migrate through agarose when incubated with a growth medium. However, when T-lymphocytes in the white cell population are exposed to an antigen to which they are sensitive they will respond with the release of lymphokines, one of which (LIF) will inhibit the migration of the ameboid leukocytes. To test for sensitivity a method similar to that first described by Clausen (1971) and modified by Astor et al (1973) is used. The migration of leukocytes is tested in three conditions: in saline as a migration control, in the presence of a known T-lymphocyte stimulator (PHA) as a no migration control, and in the presence of the antigen in question. Since metal ions are haptens, which must be complexed with protein carriers to be antigenic, we incubate white cells with metal chlorides and serum as a source of protein to assay for metal sensitivity. The method has been used with chlorides of nickel, cobalt and chromium (Brown et al 1976b Merritt et al 1979a, 1979b).

The results of the clinical studies have demonstrated three classifications of patient response (Merritt et al 1979a, 1979b). Patients with no metal sensitivity show good leukocyte migration except in the presence of PHA. Patients with metal sensitivity show good migration except in the presence of PHA and the metal salt(s) to which they are sensitive. The third patient classification is that of no cell migration in any of the test conditions. These patients have all had metal implants at the time the test was performed. Many of the implants were associated with

pain, loosening or skin rashes. Later the implants were removed and skin tests showed good cell migration in the presence of PHA and one or two of the three metals. We have hypothesized a condition of no cell migration is due for the presence of a sensitivity to the implant.

It is the correlation between the LIF results, skin test results and tissue reaction to metallic implants that is the subject of this report. In order to examine the reaction in detail an animal model was developed. The New Zealand white rabbit was used as it is large enough to accommodate orthopedic implants appropriate for use and to be used repeatedly as a source of 10 ml of blood for performing the LIF test. Sensitivity and cortical bone reaction were selected for this investigation because of the predominance of nickel sensitivity with screws in the clinical study. Stainless steel screws were utilized because of availability. In this paper we describe the ability of the rabbit to develop metal sensitivity and the condition of no cell migration, a correlation between LIF test results and a correlation between LIF test results especially no cell migration and severity of tissue reaction to stainless steel screws.

MATERIALS AND METHODS

Rabbits. New Zealand white rabbits of both sexes 3–4 kg in weight were used in three groups. They were housed in individual cages with food and water *ad libitum*. The animals were assigned to two groups: those that received stainless steel screws and those that did not. The screws were implanted 4–6 weeks prior to implantation.

Immunization. Rabbits were sensitized with 0.5 ml of 1 per cent NiCl_2 in complete adjuvant. Three weeks later they received a booster injection of 0.5 ml of 2 per cent NiCl_2 in incomplete adjuvant. Thereafter they received 0.5 ml of 0.2 per cent NiCl_2 every 4–6 weeks before sacrifice.

r sensitization

test At operation 10 ml of blood was from the central ear artery into a heparinized Blood was obtained similarly every 3 after operation and at sacrifice. The test ne as previously described (Merritt et al. Briefly, the buffy coat was obtained after station of the rbc's with dextran. The buffy coat cells were then incubated with nd serum with Phytohemagglutinin (PHA) stive control for LIF production, and with is a cell migration control. The incubated s were then pipetted into 3 mm holes d into agarose containing growth medium. stance the cells migrated in the presence of al salts was compared with the distance ls with no metal salt challenge migrated igration in the presence of metal salt ge usually fell into one of two categories: an 20 per cent of control or more than 80 nt of control migration. Therefore, in ance with standard immunologic procedure, cells with metal salt challenge migrated less 0 per cent of the distance the control cells ed, then the rabbit was said to be sensitive el. The rabbits were tested for LIF produc- nd also for the situation of being non-ors. Cell viability studies were done on the t rabbits using the exclusion of 0.4 per cent blue in saline (GIBCO with GIBCO ol) as an indicator of viability.

in test The back of each rabbit was shaved urs prior to sacrifice, and 0.1 ml of 0.2 per nd of 0.02 per cent NiCl_2 were injected id ite was observed at 4-6 hours, 24, 48, and urs after injection for evidence of induration ythema. The reaction spots were graded lung in diameter: a spot 2-3 mm in diameter alled 1+, 3-5 mm 2+, and >5 mm 3+.

ry Rabbits were placed under general Jesta for insertion of $\frac{1}{4}$ inch 316 LVM finger s (Zimmer USA) or 27 x 12 mm 316 LVM s (Synthes). Screws were inserted bilaterally he proximal humeri. There were two groups nimals: un.injected controls and rabbits nized 4-6 weeks previously, and peratively with NiCl_2 . Rabbits were iced 3, 9, or 16 weeks post insertion of the . The 16-week rabbits received the Zimmer s, the others received the Synthes screws.

logy The bone fragment containing the r was fixed in Bouin's, embedded in ylmethacrylate, and sectioned with a Zeiss all' (Perren & Geret 1979) making a cross

Table 1 The number of rabbits responding with LIF and having a positive skin test as shown for the controls and the rabbits injected with NiCl_2 . They were sacrificed at 3, 9, or 16 weeks after implantation of a 316 LVM bone screw

		Size of group	LIF	Non-migrator	NiCl_2 skin test				
					0.2%	0.02%	0.02%	0.02%	0.02%
					1+2+3+	1+2+3+	1+2+3+	1+2+3+	1+2+3+
3 wk	control	4	0	0	0	0	0	0	ND*
	NiCl_2	5	5	0	5	0	0	0	ND
9 wk	control	6	0	0	1	0	0	0	0
	NiCl_2	8	9	5	3	3	3	3	3
16 wk	control	3	0	0	0	0	0	0	ND
	NiCl_2	5	5	2	3	2	0	0	ND

*ND=not done

section of the bone through the screw without decalcification of the bone or removal of the screw. The sections were stained with Giemsa stain and mounted with Eukitt. The sections from the left and from the right humeri were examined for each animal.

The sections were examined without knowledge of the sensitization status of the rabbit and the interface tissue was scored on a 0 to 5+ scale for syncytial giant cells, foreign body giant cells, bone, fresh rbc, old rbc, inflammatory cells, eosinophils and necrotic or cystic tissue. The bone marrow away from the screw thread was also examined and scored as normal or unhealthy (many inflammatory cells or areas of necrosis).

The average score for the histologic evaluation was inspected, and statistical analysis was done only in those categories revealing differences. The standard deviation was determined for the controls and then the scores on the animals injected with NiCl_2 were inspected for the number falling 2 standard deviations (σ) above or below the mean for the control.

RESULTS

Sensitization

(1) *Skin test* The reactions were absent at 4-6 hours, appeared at about 24 hours, and peaked by 48 hours. As can be seen from the data presented in Table 1, all rabbits

Table 2 The results of the histologic evaluation of the bone-screw interfaces and the marrow are recorded for rabbits with and without the injection of NiCl_2 and sacrificed 3, 9, and 16 weeks after implantation of the 316 L stainless steel bone screw

	3 week				9 week				16 week	
	Control (8)		NiCl_2 (10)		Control (12)		NiCl_2 (17)		Control (11)	
Interface	Ave	$\pm 2\sigma$	Ave	$>2\sigma$	Ave	$\pm 2\sigma$	Ave	$>2\sigma$	Ave	$>2\sigma$
Syncytial giant	3.4		3.3		2.1		2.7		1.8	
Foreign body	0.50	0-1	2.4	81	0.5	0.76-1.76	1.3	111	0.16	0-5
Bone	0.62		1.0		1.4		1.2		2.0	
Old rbc	2.2		1.2		1.4		2.2		1.0	
New rbc	0.87		0.5		0.42		0.94		0.5	
Inflammatory cells	1.1		1.4		0.17	0-47	3.4	161	0.33	0-25
Eosinophilic cells	0.75		0.7		1.3	0.76-3.9	2.2	31	0.16	0-115
Necrosis or cysts	0		0.2		0.8		0.41		0	
Bone marrow unhealthy	3		10		2		13		0	

immunized with NiCl_2 were skin test positive to 0.2 per cent NiCl_2 . Only the 9 week rabbits were tested with 0.02 per cent NiCl_2 and three of them were positive. One of the 13 unimmunized rabbits was skin test positive to 0.2 per cent NiCl_2 but not to 0.02 per cent. Skin testing with 2 per cent NiCl_2 gave a toxic reaction in control rabbits in a preliminary study and was not used for further testing.

(2) *LIF test* All rabbits immunized with NiCl_2 produced LIF to NiCl_2 whereas no control rabbit produced LIF. None of the 3 week rabbits were nonmigrators. 5/9 of the 9 week rabbits had become nonmigrators (1 at 6 weeks and the others at 9 weeks) and in the 16-week series two rabbits had become nonmigrators, both at 9 weeks. The trypan blue cell viability test gave similar results for the migrators and the nonmigrators with about 90 per cent viable cells.

Histology The results of the histology grading are recorded in Table 2. The scores for each group and sacrifice period were averaged. The progression in histologic

response to screws by the marrow of rabbits from 3 weeks to 9 weeks was a decrease in the amount of foreign body giant cell lining of the screw and an increase in the amount of bone around the screw (Figure 1). There was a decrease in inflammatory cells in the thread silhouette and the cellular bone marrow decreased somewhat.

The progression in the marrow response to screws by the rabbits seen in the 16-week series was more advanced. It involved only a moderate decrease in syncytial giant cells and foreign body cells. The amount of bone did not increase to the extent seen in the 9-week series. The inflammatory cells and eosinophilic staining cells decreased and necrosis became evident.

It is evident from these data that the group sacrificed at 3 weeks showed no difference between the unimmunized groups except the NiCl_2 injected group did have a small amount of foreign body giant cells with a score of 2.2 (2.0 \pm 0.2) above the control. Foreign body giant cell lining typical of the



Figure 1 The progression in the histologic reaction to the bone screws showed increased bone formation from (A) 3 weeks to (B) 9 weeks and (C) 16 weeks.

the development of foreign body type cells as seen more frequently in the injected animals. The bone marrow of nickel injected animals seemed to be more filled with inflammatory cells, however, the control and the injected animals had very cellular bone marrows. One injected animal showed a small cystic-necrotic area



Figure 2 The major tissue-screw interface in the 3 week control rabbits (A) was formed by the multinucleated syncytial cell while the NiCl_2 injected group (B) showed a lining of multinucleated cells with inflammatory or foreign body reaction.

By 9 weeks, more differences between the groups were evident. Compared with the controls, the injected group showed an increase in the foreign body giant cells with 11/17 (65 per cent) of the sections having scores greater than 2σ above the mean for the controls, a marked increase in inflammatory cells with the average and 16/17 (94 per cent) of the sections above 2σ above the controls, and a small increase in eosinophilic cells with 3/17 (17 per cent) sections greater than 2σ above the controls. Figure 3 depicts an interface lining of the inflammatory cells in the nickel injected group compared to bone formation in the control group. In the nickel injected group, the bone marrow was more cellular with inflammatory cells than in the controls, as shown in Figure 4.

At 16 weeks, the nickel injected group, compared to the controls, showed an increase

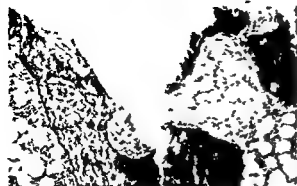


Figure 3 At 9 weeks the control rabbits (A) were forming bone at the tissue-screw interface while the rabbits injected with NiCl_2 (B) showed an inflammatory response



Figure 4 At 9 weeks the control rabbit (A) had normal appearing bone while the injected rabbit (B) had a very inflamed area with many inflammatory cells

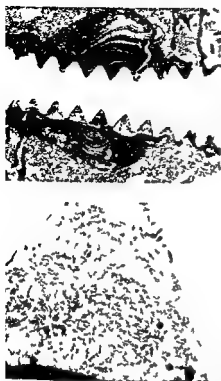
in the foreign body giant cells (average and 5/10 [50 per cent] sections above 2σ), in the inflammatory cells (average and 7/10 [70 per cent] sections above 2σ), and in eosinophils (average and 6/10 [60 per cent] sections above 2σ). The bone marrow still was cellular with inflammatory cells in the nickel injected group. Two of the nickel injected rabbits had developed areas of necrosis.

Nonmigrators The evaluation of the animals injected with NiCl_2 included both those producing LIF and those that became nonmigrators. Comparison of the nonmigrators with those sensitized animals still showing cell migration revealed some differences. There tended to be an increase in foreign body giant cells and a decrease in eosinophils in the nonmigrators compared to animals only producing LIF. These differences were not significant. However, necrotic reactions

were seen only in the nonmigrators. At 9 weeks, this involved small areas of the screw thread silhouette. The necrotic reaction was seen in a (44) migrator who had developed a core with giant cells budding from a tissue layer with necrotic layer from screw thread silhouette in a region of the screw-tissue interface. This is shown in Figure 5.

DISCUSSION

The choice of an animal model is a problem in human medicine. The guinea pig has classically been an animal of choice for modeling allergic disease and has been studied quite extensively. It is an excellent model for chronic allergic disease and contact dermatitis.



This was the most severe necrotic reaction and was seen in a 16-week NiCl₂ injected. The tissue-screw interface (A) shows large necrosis with higher power (B) revealing the thread form with giant cells in the necrotic area. (C) other giant cells budding into the area.

However, it would appear that the pig can be sensitized to nickel only with difficulty if at all (Turk & Parker 1973). Furthermore the guinea pig has not been used as a model for orthopedic surgery as the human population has a significant level of nickel sensitivity of 11–13 per cent (Turk et al 1973, 1975). In patients being tested for dermatitis (Turk et al 1973, 1975) it was decided to study the problems of nickel sensitivity in the rabbit which was also good for histologic studies. It would appear from the results presented here that the rabbit can be used as an excellent model for hypersensitivity. It would also appear that the LIF skin test are well correlated with the results of the one out of 13 un.injected animals who gave a positive skin test and no

The situation of no cell migration was a surprising finding when it was first observed in the clinical study (Brown et al 1976b). The test result of no migration would usually be interpreted to mean that the test had not worked. However, in both the clinical and rabbit studies, other tests performed the same day and with the same reagents have shown good migration. Furthermore, these same patients or animals have repeatedly demonstrated no cell migration. Thus we do not believe the condition is an indication of a bad test. Cell viability studies using trypan blue exclusion have not revealed any differences in either the human or the animal studies between those showing good migration and those showing no cell migration. We have hypothesized that the condition of no migration indicates that the lymphocytes have been challenged by the antigenic nickel protein complexes from the implant site, and that the result is indicative of an individual being sensitive and reacting to the implant. Normal cell migration has returned in the human patients following removal of the implant (Brown et al 1976b, Merritt et al 1979a, 1979b).

The histologic reaction to the screws in the un.injected animals was quite consistent from animal to animal and was typical of the normal reaction to an inert foreign body. Thus it was possible to determine mean and standard deviation values for the cell populations seen in these control animals. The tissue reaction of the injected animals was more varied. In these animals the histologic evaluation revealed changes typical of a host defense reaction. There was a change from syncytial giant cells to inflammatory cells, with some animals developing foreign body giant cells and necrotic areas. The variation in the cellular reaction in these sensitized animals, which may have been due in part to the variation in the response to the nickel injections made it difficult to treat them as a group. The standard deviation of the histologic evaluation in the sensitized animals was, not surprisingly, much greater than that

for the controls. In no category would 2 standard deviations of the mean for the sensitized animals fall above or below 2 standard deviations for the control animals. Nevertheless, many differences were evident between the groups with many of the sensitized animals having histologic evaluations greater than 20% above the mean for the controls.

The reaction depicted in Figure 5 shows the worst reaction we have seen to date, with a large necrotic area in the medullary area of the screw thread silhouette. This and several other severe necrotic reactions were associated with the condition of no cell migration in the LIF test. It is well known that ions are released by implants *in vivo* (Laing et al. 1967), and it is hypothesized that these severe necrotic reactions are the manifestation of a positive deep tissue reaction to nickel being released, and that the condition of no migration is diagnostic for the reaction. A small cystic-necrotic area was seen in one 3 week, LIF producing animal. While this animal had not become a non-migrator, it is possible that this reaction is indicative of the development of a sensitivity reaction to the metallic implant.

The sequence of events would appear to be that the sensitive animals develop an increased reaction to the implant as evidenced by the histologic examination. When the reaction becomes severe to the point of having necrotic areas, then systemic change such as the modification of normal leukocyte migration is detected by the LIF test.

This study would seem to document that a sensitized animal can react to the presence of an implant. The development of the reaction is slow, probably because of the necessity for the screw to begin undergoing processes such as abrasion or corrosion leading to the release of sufficient ions to stimulate the sensitized cells. As we will report subsequently in more detail, we have observed that electropolished 316 LVM implants are negative to the dimethylglyoxime (DMG) test (Fisher 1977), but are positive to DMG after being subjected to an electrochemical corrosion pro-

cedure. We have also observed positive tests in clinically retrieved implants with available nickel on the implant as a result of the *in vivo* corrosion. Thus, it is reasonable to hypothesize that a reaction would probably not cause terms of pain, swelling or bony device in the human population for a long time after implantation.

This study has addressed the question of a metallic implant in a sensitized animal. It does not address the ability of an animal to cause sensitivity, nor does it address the question of allergy developing to an implant has been in place for some time. The histologic reaction may be evident at the time sequence certainly would be prolonged in these conditions.

The histologic evaluation of the tissue at the interface tissue lining the screw appears to be soft and fragile. The preservation of the tissue for embedding in methacrylate for removal of the implant is of importance in evaluating the tissue response to implants. Removal of the implant after fixation but prior to embedding would remove much of the actual reaction. Laboratories not equipped with a device capable of cutting metals or a chemical capable of dissolving the implant for sectioning (Brown & Simpson 1977).

CONCLUSION

These studies demonstrate that the LIF test is a good model for studying sensitivity reactions. The results of the LIF test and the histologic evaluation show a good correlation. The tissue at the interface of the implanted stainless steel screw shows an increased reaction in the nickel sensitive animals. The most severe reactions were seen in animals which had developed the condition of nonmigration. This study demonstrates the potential of the LIF test as a rapid method for repeated testing for sensitivity.

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EFFECT OF DRINKING WATER FLUORIDATION ON THE FLUORIDE CONTENT, STRENGTH AND MINERAL DENSITY OF HUMAN BONE

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The effect of drinking water fluoridation on the fluoride content of human bone, on cancellous bone strength and on the mineral density of bone was studied by analysing 158 autopsy samples of the anterior iliac crest from persons from two different areas. In the samples from the town of Kuopio, where drinking water has been fluoridated since 1959 the fluoride concentrations were considerably higher than in samples from the surrounding area where low-fluoride drinking water is used. The fluoride content of bones from Kuopio increased significantly with age, while considerably less change with age was found in samples from outside Kuopio. The highest fluoride content in bone ash was observed in women with severe osteoporosis.

Cancellous bone strength measured by a strain transducer was statistically significantly higher in women with chronic immobilizing disease from Kuopio, compared with the corresponding group from outside Kuopio. No statistically significant differences in bone strength were found in men. There were no statistically significant differences in bone mineral density, as measured by gamma ray attenuation, between the samples from the fluoridated and non fluoridated areas.

Key words: bone mineral density, bone strength, fluoride, osteoporosis

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Drinking water fluoridation has been carried out in many communities for the prevention of dental caries. The effects of the fluoride content of drinking water on bone have been studied by several authors (Blayney et al 1958, Jackson & Weidman 1958). It has been found that the amount of fluoride in bone increases with age and that it increases with age in drinking water and that it increases with age in drinking water and that it increases with age in drinking water (Geever et al 1971, Kneiss 1969). On the other hand, a massive intake of fluoride, as in areas with endemic fluorosis, has a deleterious effect on the skeleton. Fluoride is also used in the treatment of osteoporosis (Cass et al 1966, Chlud 1977, Franke et al 1974, Hansson & Roos 1976, Jowsey et al 1972, Kruse et al 1978, Rich & Ivanovich 1965), but its usefulness is still disputed (Inkovaara et al 1975).

Kuopio, the largest town in the North Savo area, is so far the only locality in Finland employing drinking water fluoridation (since

1971, Kneiss 1969). On the other hand, a massive intake of fluoride, as in areas with endemic fluorosis, has a deleterious effect on the skeleton. Fluoride is also used in the treatment of osteoporosis (Cass et al 1966, Chlud 1977, Franke et al 1974, Hansson & Roos 1976, Jowsey et al 1972, Kruse et al 1978, Rich & Ivanovich 1965), but its usefulness is still disputed (Inkovaara et al 1975).

1959) On the other hand, the waters of the surrounding communities have a low natural fluoride content according to Korhonen et al (1975) the average is below 0.1 ppm and the range is from 0.02 to 0.32 ppm. The fluoride content of tap water in Kuopio was found in the same investigation to be 0.97 ± 0.02 ppm.

The purpose of the present work was to study the effect of long-term fluoridation of drinking water on the fluoride content of human bone, mineral density of bone and cancellous bone strength. The work was based on cadaver samples from donors from the town of Kuopio and the surrounding areas.

MATERIALS AND METHODS

The bone material Bone samples were obtained from autopsies of 66 women and 92 men. There were 36 females and 69 males who had died suddenly due to acute coronary artery disease or accidents. In 30 women and 23 men the cause of death was a chronic immobilizing disease for which they had been treated in institutions for chronically ill patients.

Fifty-three of the cases, 28 women and 25 men had been residents in Kuopio from the beginning of fluoridation (14–18 years). The rural non-fluoridated material consisted of 38 women and 67 men.

Bone specimens, about 40 mm long and 10 mm thick containing both cortical and cancellous bone were taken by saw at autopsy from the anterior iliac crest and fixed in 40 per cent ethyl alcohol. The samples were collected between 1973 and 1978.

Determination of fluoride The bone specimens were taken from the preservation solution and dried gently with soft tissue. Three types of samples were taken for analysis (Figure 1).

- 1 "Mixed bone sample" About one-third to one-half of the lower end was cut off from each specimen and taken for analysis. The average ash weight of these samples was about 450 mg.
- 2 "Cortical bone sample" A small piece of hard bone was cut from the upper end of the specimens. The average ash weight of these samples was 38 mg.
- 3 "Cancellous bone sample" About 4 mm x 4 mm of cancellous bone was cut from the centre of

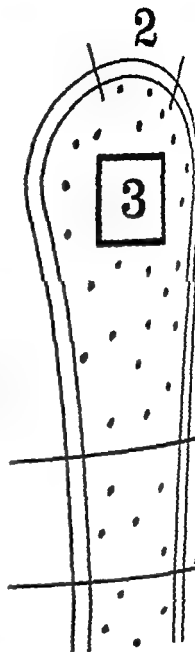


Figure 1 Three types of samples taken from iliac crest.

the upper end of the specimens. The ash weight of these samples was 100 mg.

The samples were transferred to porcelain crucibles and weighed. They were covered, heated over a flame at 550°C , cooled, and the percentage of fluoride determined. About 40 mg of ash were

1 samples for analysis. The ashes of the 13 samples were analysed *in toto* fluoride ion was determined with an ion electrode (ORION 94-09). In the earlier study fluoride was separated from the ash by microdiffusion according to the method described by Kari et al (1976). Later, it was found that fluoride could be determined in the dissolved bone ash if the calcium was complexed by an efficient enough complexing agent e.g. citrate (Kauranen 1977). The ash was dissolved in 1 ml of 4 M HNO_3 (K. Schnellman 1975), 10 ml of 5 M acetate buffer, pH 5, and 1.5 ml of 2 M citrate was added. The solution was diluted to 10 ml and the fluoride determined by the ion electrode. Because the fluoride contents were very high, a constant potential of the electrode was generally reached in less than 5 min. Calibration was performed by taking known amounts of standard sodium fluoride solution and using the same procedure. The calibration line was linear over the concentration range observed in the bone samples. Reproducibility and recovery were tested using the IAEA calculated animal reference sample No. A 3/1/1974. The fluoride recoveries were 99.6 per cent. Eight determinations of the fluoride content of the IAEA sample yielded a value of 1.16 F with a standard deviation of 11 ppm, or 0.9 per cent.

Determination of cancellous bone strength Trabecular bone compressive strength was determined with a strain transducer described by Korvisto et al (1976). The square wave from the transducer was fed to a frequency-voltage converter and the analogue voltage was recorded with a transient recorder (Biomation 1015).

Determination of bone mineral density Trabecular bone mineral density was measured with a technique of the gamma ray attenuation method (Cameron & Sorenson 1963). The bone sample was immersed in a water bath and a beam of 60 keV photons from a ^{45}mCi source was passed through the water bath. Results were calculated from the equations

$$\text{BMD} = a_0 + a_1 S + a_2 S^2,$$

$$S = \frac{1}{\ln K} \sum_{i=1}^k \ln(N_{\text{in}}/N_{\text{out}})$$

where BMD is the bone mineral density, a_0 , a_1 , a_2 are constants and N_{in} and N_{out} the numbers

of photons being transmitted through the water bath without and with the bone sample, respectively. K is the number of measuring sites (8-12 in our case) and l the bone length in the direction of the beam. The constants a_0 , a_1 , and a_2 were obtained experimentally by determining the bone mineral density by ashing 28 specimens, and by fitting a second degree polynomial to the calculated S -values.

Absorptiometry gives more reproducible results than ash content/volume determination, since every result was averaged over samples from 8-12 sites in the area of cancellous bone. Due to the porosity of the trabecular bone, volume determinations are not accurate (Momeni et al 1976). (Details of the procedure are available from the authors.)

RESULTS

Fluoride content of bone The fluoride content of bone ash as a function of age is shown in Figure 2. The more rapid accumulation of fluoride in the bones of subjects living in the fluoridated area compared with the non-fluoridated area is evident. The difference in the slope of the regression lines is statistically highly significant ($P < 0.001$). The slope for the samples from women from Kuopio is also steeper than the corresponding slope for men ($P < 0.001$). The scatter of the fluoride content is particularly large for the samples from women from Kuopio. There was no difference in the fluoride content of samples from cases of sudden death and death following chronic immobilizing disease in either sex in or outside Kuopio (Figure 2). The highest fluoride contents were associated with low ash contents. The average ash and fluoride contents for three types of bone samples are given in Table 1.

Cancellous bone strength and mineral density

The bone strength of subjects as a function of age is presented in Figure 3. The trabecular bone strength and mineral density of samples from subjects aged over 45 are shown in Table 2. Younger cases were excluded from the comparison due to the relatively small amount of fluoride in bone in the fluoridated area (Figure 2). Female and male subjects were analysed in

1959) On the other hand the waters of the surrounding communities have a low natural fluoride content according to Korhonen et al (1975) the average is below 0.1 ppm and the range is from 0.02 to 0.32 ppm. The fluoride content of tap water in Kuopio was found in the same investigation to be 0.97 ± 0.02 ppm.

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Determination of fluoride The bone specimens were taken from the preservation solution and dried gently with soft tissue. Three types of samples were taken for analysis (Figure 1).

1. **Mixed bone sample** About one-third to one-half of the lower end was cut off from each specimen and taken for analysis. The average ash weight of these samples was about 450 mg.
2. **Cortical bone sample** A small piece of hard bone was cut from the upper end of the specimens. The average ash weight of these samples was 38 mg.
3. **Cancellous bone sample** About 4 mm \times 4 mm of cancellous bone was cut from the centre of

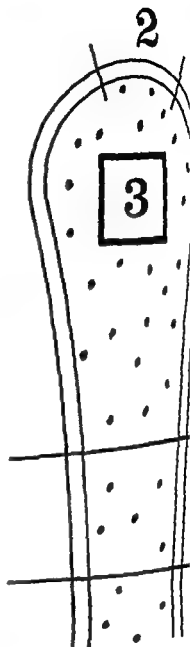


Figure 1 Three types of samples taken iliac crest

the upper end of the specimens. The ash weight of these samples was 24 mg.

The samples were transferred to porcelain crucibles and weighed. They were covered, heated overnight in a muffle furnace at 550 °C, cooled, and the percentage of fluoride determined. About 50 mg of ash was used.

Table 1 Average ash and fluoride contents of bone specimens from which three types of samples were analysed. The range of results is given in parentheses. m =slope of linear regression, r =correlation coefficient of bone fluoride content on age. N =number of specimens analysed.

From Kuopio						Outside Kuopio					
N	Age	Ash (%)	F (ppm)	m	r	N	Age	Ash (%)	F (ppm)	m	r
<i>Women</i>											
Cancellous bone	24	68.6 (44-85)	19.3 (7.3-36.1)	2070* (759-4140)	44.1 0.488	23	64.4 (31-92)	18.9 (8.2-35.5)	622 (283-1500)	11.6 0.582	
Cortical bone	24	68.6 (44-85)	35.6 (14.6-51.5)	1720* (621-3620)	32.0 0.345	23	64.4 (31-92)	38.5 (12.9-59.4)	443 (214-745)	4.73 0.443	
"Total" bone	24	68.6 (44-85)	29.0 (17.0-43.6)	1280* (399-2360)	28.1 0.599	23	64.4 (31-92)	27.6 (13.4-43.6)	384 (144-790)	5.43 0.621	
<i>Men</i>											
Cancellous bone	14	56.4 (24-86)	26.3 (14.2-41.2)	1360 (804-2360)	17.4 0.658	17	52.6 (20-86)	24.7 (13.8-36.8)	447 (142-735)	3.28 0.340	
Cortical bone	14	56.4 (24-86)	46.1 (35.4-55.7)	1290 (660-2740)	22.7 0.737	17	52.6 (20-86)	41.4 (25.1-58.2)	462 (150-769)	3.56 0.429	
"Total" bone	14	56.4 (24-86)	29.5 (20.2-37.5)	901 (347-1980)	18.2 0.769	17	52.6 (20-86)	29.6 (20.0-53.5)	319 (106-539)	3.33 0.769	

*One exceptionally low case omitted from range values.

Table 2 Trabecular bone strength and mineral density (± 1 SD) in subjects over 40

	From Kuopio	From outside Kuopio	Difference %	S.E. significance
<i>Females, sudden death</i>				
Number of cases	8	13		
Age (years)	66.4 \pm 4.3	65.5 \pm 2.9		N
Bone strength (10^4 N/m ²)	9.06 \pm 0.50	8.29 \pm 0.41	+9.2	P<0.05
Bone mineral density (kg/m ³)	234 \pm 17	218 \pm 27	+7.3	N
<i>Females, chronic disease</i>				
Number of cases	13	11		
Age (years)	69.1 \pm 2.6	65.4 \pm 2.9		N
Bone strength (10^4 N/m ²)	8.85 \pm 0.57	7.62 \pm 0.29	+16.1	P<0.05
Bone mineral density (kg/m ³)	211 \pm 13	191 \pm 22	+10.5	N
<i>Males, sudden death</i>				
Number of cases	11	33		
Age (years)	63.8 \pm 2.8	60.4 \pm 1.7		N
Bone strength (10^4 N/m ²)	9.69 \pm 0.60	10.40 \pm 0.34	-6.8	N
Bone mineral density (kg/m ³)	232 \pm 9	239 \pm 6	-2.9	N
<i>Males, chronic disease</i>				
Number of cases	5	10		
Age (years)	54.6 \pm 3.4	61.5 \pm 2.7		N
Bone strength (10^4 N/m ²)	9.10 \pm 0.26	9.36 \pm 0.52	-2.8	N
Bone mineral density (kg/m ³)	212 \pm 8	205 \pm 10	+3.4	N

disease, the trabecular bone strength was almost significantly higher in cases from Kuopio compared with cases from outside Kuopio. The trabecular bone mineral density was 7.3 per cent and 10.5 per cent higher, respectively. However, due to large variations, the differences are not statistically significant. No statistically significant differences in bone strength and mineral density were found between the corresponding male groups.

DISCUSSION

There is a loss of bone mineral in chronic diseases that cause physical inactivity. The disease itself, such as chronic renal failure, alcoholism, diabetes mellitus, may for one reason or another have a rarefying effect on the skeleton (Wheeler 1976). We believe that our

rough division of patients into two: chronic immobilizing disease and death, separates the osteoporoses from cases with a normal mineral status.

In osteoporosis bone resorption is in relation to new bone formation. Fluor transforms hydroxyapatite to fluorapatite (Posner et al 1963) which is more resistant to resorption than normal hydroxyapatite (Pett & Cohen 1967). Moreover, it activates osteoblasts (Jowsey et al 1968) and in humans with fluorosis that the seams thicken and mineralization is increased, resulting in denser bone tissue. However, this kind of bone may have histological features of osteomalacia, and its physical properties may be abnormal (Riggins et al 1974; Lamm et al 1974). Some human studies have shown that the tensile strength of bone seems to decrease and the compressive strength to increase.

using fluoride content of bone (Evans & 976, Franke et al 1976).
 Stein et al (1966) stated in their
 biological study that osteoporotic
 were fewer in areas where the fluoride
 of the drinking water was high,
 ed with areas where it was low. Korns
 could not confirm the beneficial effects of
 in the prevention of osteoporosis in his
 on artificial fluoridation of drinking
 Geever et al (1971) were unable to show
 et of fluoridation at the 1 ppm level on
 stology
 ound that the fluoride content of iliac
 ncreases steadily with age without
 g out at a higher age, as suggested by
 & Weidman (1958). It is possible
 to 18 years of fluoridation in Kuopio
 short a time for a plateau to be
 l. The fluoride content of cancellous
 was generally greater than that of
 l bone, probably due to more active
 lism. This is in agreement with the
 t that fluorapatite is more resistant to
 ion than hydroxyapatite.
 site having consumed drinking water
 ation for less than 20 years, some
 cases in Kuopio had quite a high
 t of fluoride in bone (up to 4000 ppm
 cellous bone ash). It is possible that
 i lifetime of fluoridation some women
 opio may experience adverse effects
 fluoride accumulation.
 question of the lower limit for a toxic
 le content in bone is still open. Jackson
 idman (1958) felt that levels above
 ppm of fluoride in fat-free dry cortical
 should be considered toxic. Riggins et
 (1974) were of the opinion that a subject
 considered to have fluorosis when the
 itration of fluoride in bone ash exceeds
 ppm.
 physical parameters used in this study,
 one mineral density and cancellous bone
 th, did not show any significantly
 cial effects of fluoridation apart from
 evidence that fluoridation may preserve
 il density and bone strength better in
 n with chronic immobilizing diseases

compared with women from the non-
 fluoridated area. This effect was not seen in
 men, but the comparison between men of
 rural and urban populations is difficult
 because of the difference in bone density
 between these populations (Helela 1969).

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INTERNAL STRESS PATTERN OF THE OS COXAE

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The stress pattern of the os coxae was evaluated from the trabecular patterns and the theoretically predicted stresses based on the principles of Wolff's law. A good correlation between the expected stress situation and the trabecular pattern was observed.

Key words: hip, os coxae, stress, trabecular pattern

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Insertion of joint prostheses into the hip has during the last 10 to 15 years become an established procedure. The insertion of an acetabular component which, in comparison with the bone, is a stiff foreign body through which the load on the hip is transmitted, must be expected to change the stress pattern in the pelvis, thereby inducing remodeling of the bone. Increasing experience with loose acetabular components has led to the foreseen that the remodeling of the bone may play a role in the long-term function of the acetabular components. As a prelude to an investigation of this problem an analysis of the normal stress pattern in the pelvis is essential. In the present study an evaluation of the normal stresses was made based on the anatomy and the loads on the hip joint. Benninghoff examined the split lines on the surface of decalcified pelvis, but to the author's mind a more thorough evaluation of the internal bony structure of the pelvis has not been made. A greater knowledge of the stress pattern inside the pelvis is necessary if the

fixation of acetabular components is to be improved.

MATERIAL AND METHODS

For the examination of the internal structure of the os coxae were used. The sacrum is not included in the investigation. The bones were prepared as dry osteological specimens and were sawn through either in a plane with a hand saw or following the curvature of the bone which may be done with an ordinary jigsaw. The lines of section are shown in Figure 1. Only the thin central area in the ala ossis iliac could not be prepared so that a distinct structure of the spongiosa was discernible.

Firstly, the patterns of the spongiosa will be described; secondly, the stress patterns that are to be expected from the shape and the load on the bone will be evaluated; and thirdly, the structure of the spongiosa will be evaluated in the light of the expected stress patterns.

In the drawings compressive stresses are shown as full lines while tension stresses are shown as broken lines. It was not possible to demonstrate all trabecular patterns in a single section and accordingly Figures 5 and 7 are composite pictures demonstrating the characteristic patterns. The trabecular patterns are also shown in Figures 2, 3,



Figure 1 Directions of the sections through the os coxae for the evaluation of the trabecular patterns

and 4 The most illustrative section was made through the center of the acetabulum and shows the bony pattern around the acetabulum.

RESULTS

Anatomical findings

The first thing to be noted is the regular trabecular pattern with two sets of trabeculae arranged at right angles to each other. These two sets of trabeculae will be described separately. In the area under the acetabular joint surface the trabeculae were seen to emerge in a radiating pattern. Anteriorly these trabeculae that arise from the most anterior 1 cm of the acetabulum run along the corticalis in the anterior part of the os ilei towards the inferior anterior iliac spine. Proximally to this they join the corticalis at an acute angle (area 1 in Figure 2). In the superior part of the joint surface the trabeculae also radiate but they soon bend posteriorly proximally so that they point towards the sacro-iliac joint (Deep to area 1 not shown in the figure). Further back the trabeculae become thicker and converge towards the sciatic notch (area 2). Distal to the sciatic notch the trabeculae run directly to the posterior corticalis which they meet at a right angle (area 3). In the most distal part of the acetabulum corresponding to the os ischii

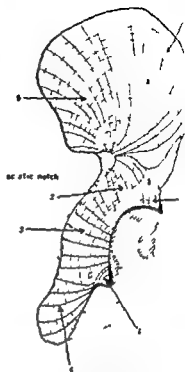
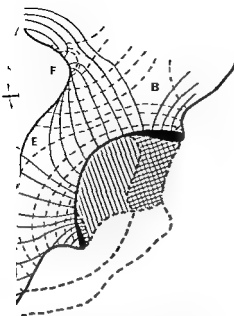


Figure 2 Drawing representing the patterns of the os coxae interpreted as stress trajectories. Full lines represent compression, broken lines represent tensile stress. The drawing is made through the center of the acetabulum at an angle of 45° to the joint surface and shows the patterns found in the marked 1 through 4 in Figure 1.

the trabeculae first traverse the condylar trusion which supports the distal end of the joint surface and then fan out towards the anterior aspect of the iliac corticalis of the posterior aspect of the iliac which is reached at a right angle (area 1). Proximal to the sciatic notch the trabeculae fan out. In this area they are dense and the structure is not always easy to define. It points towards the joint surface of the acetabulum (area 6). The trabecular system runs forward at right angles to the iliac corticalis way to the anterior superior iliac spine. In the area deep to the posteriorly described section the pattern changes. At this level, marked in Figure 1, the section goes through the center of the joint surface. The drawing of the joint surface is found in Figure 3 and a photograph of the bone is seen in Figure 6. In this area



3 Drawing representing the trabecular pattern of the os coxae in the deep part of the ilium. The section is made through the ilium corresponding to the line marked 2 in Figure 1.

ae divide so that only the most part goes directly to the corticalis the acetabulum. From the superior the surface the trabeculae run anterior and medial to the sciatic such they pass with a slight swerve it and then continue towards the joint. The patterns are not as some of the trabeculae enter the bone on the way and therefore cannot be seen.

Trabecular pattern in the inferior ramus of the os pubis is shown in Figures 4 and 7. Positioned above the trabeculae run the posterior surface of the proximal the tuber ischii, but further distally in the same direction so that in the inferior they run across the bone. In the pubic the trabecular system reaches the symphysis at right angles. In the inferior ramus of the pubic bone the trabeculae run upwards in an increasingly pattern and at the root of the superior

sacroiliac joint →

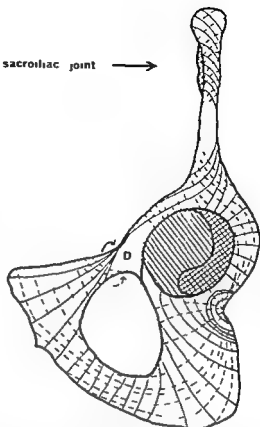


Figure 4 Drawing representing the trabecular pattern of the os coxae. The section is made through the os pubis, the inferior ramus and the acetabulum corresponding to the section marked 4 in Figure 1.

ramus they join the thick cortical bone found there. In the ala ossis ilii this system of trabeculae is seen to curve into the external corticalis and from there to the sacro-iliac joint (Figure 4).

The second system of trabeculae run at right angles to the one just described. They run concentrically around the acetabulum as a layer of thin shells which increase in thickness posteriorly where they run parallel to the corticalis (area 2, Figure 2). Proximally to this they run together around the sciatic notch in a 0.5 to 1 cm thick cortical structure which however retains its oriented nature as is seen when the section is stained with Indian ink. More proximally at the level of the sacro-iliac



Figure 5: Composite photograph of trabecular patterns, corresponding to the drawing in Figure 2



Figure 6: Photograph of the trabeculae corresponding to Figure 3

joint these trabeculae fan out over the ala ossis ilii, finally running parallel to the iliac crest as far as the anterior edge of the pelvis which they meet at right angles. Centrally in the ala the bone is so thin that the spongiosa disappears so that no structure can be found there. In the deeper section these trabeculae are seen to alter their course so that a point with a very thin trabecular structure appears just below the posterior cortex distal to the sciatic notch. The reinforcement of the sciatic notch which at the center is condensed to cortical bone is at this level seen as an area of dense but separated trabeculae that form a small dome-shaped configuration. The fact that this structure is seen at an angle accounts for the irregularity of the trabeculae. The bone structure in this area is unusually complicated and in the preparations there was a thin area with loss of orientation of the

structure at the point marked F. The area distal to the sciatic notch is not

Distally, in the tuber ischii the fan out to form a gothic-arch pattern. The first set of trabeculae and then curve first and medially into the inferior ramus. Here they have a slightly spiral course. In the pubic bone they turn upwards across it. Closer to the acetabulum the superior pubic ramus the course again to spiral. They turn in under the line of the superior ramus where they enter the iliac fossa. At the acetabulum they are as concentric lamellae.

Apart from the general pattern is above certain areas consistently. It changes from the uniform distribution of trabeculae found elsewhere. Concentric trabeculae into star-like configurations found in two places, although the



Figure 7 Composite photograph of the trabecular patterns corresponding to Figure 4



Figure 8 Detail of trabecular pattern around the acetabulum

different. The first is seen at the sciatic on Figure 2 and has been described. The second is seen just inferior and anterior to the acetabulum on Figure 4. In structure the one system of trabeculae are completely concentric and the other has a ring configuration. In addition to these systems of concentrated trabeculae six points are found of uniformly very thin trabeculae at the same time seemed to lose all definition. The points are marked A through Figures 2, 3, and 4. Point A corresponds to a thin spot in the ala ossis ilii, point B is located at the proximal end of the acetabular neck and C is the distal end. Point D is located at the base of the superior ramus of the pubic bone where the trabeculae spiral and at right angles to each other going into the corticalis at this point. Points B and C can be seen in Figure 3. The significance of these points will be discussed further.

Expected stress patterns

As a mechanical structure the pelvis may be considered to consist of four roughly triangular ring structures (Figure 9). Each half of the pelvis consists of two rings that support the acetabulum. Each half of the pelvis is supported posteriorly by the sacrum and anteriorly they meet in the symphysis. The superior ring like structure is formed by the iliac bone. The anterior part of the ring goes from the acetabulum along the anterior part of the iliac bone to the anterior superior iliac spine, the posterior part goes from the top of the acetabulum to the sacro-iliac joint and is the strongest structure in the pelvis. The third side of the ring is formed by the iliac crest. This ring is closed by the squama. The lower ring is formed by the pubic and ischial bones. It also supports the acetabulum.



Figure 9 Antero lateral view of the pelvis. The system of the two triangular "ring" structures is indicated.

at the end of the facies semilunaris, but it is twisted $80-90^\circ$ in relation to the superior ring (Figures 1 and 9). Both ring structures are twisted in themselves especially the distal one, as the symphysis is positioned at an angle of about 45° to the frontal plane. These facts are of importance in a detailed analysis of the expected stresses in the pelvis. It has been demonstrated by Greenwald & O'Connor (1971) that at loads that exceed 25-50 per cent of body weight there is total contact between the joint surfaces in the hip joint. It will be seen from this that the transition between the various stress situations will be gradual and that in all positions of the hip, forces will be transmitted over the entire surface - except in the swing phase. However, the direction of the resultant will vary and this is of importance in the determination of the stress pattern. In the

standing position the hip is loaded along the axis which goes from the sacro-iliac joint distally - anteriorly to the top of the acetabulum. This axis has an inclination anteriorly of about 15° and also is tilted (Debrunner 1975) depending on the position of the pelvis and its tilt. The axis coincides quite closely with the common resultant vector (Pauwels 1965, 1975, Harnacher & Roesler 1977). In the standing position the main force is directed towards the sacro-iliac joint; there will only be a modest bending moment distal to the sciatic notch. However, the resultant will point downwards and there will be an increasing moment as the lower part of the acetabulum is pressed backwards. Such a stress will give rise to compression on the posterior aspect of the tubercle of the ilium. This bending force is checked by the interosseous ligaments which in their turn hereby are put under tensile stress. A further tensile force is created by the loading of the hip in flexion which involves the muscles that stabilize the pelvis and the hip (short postero-lateral muscles, hamstrings, adductors). These tensile stresses will tend to pull the greater trochanter forwards thereby causing stresses in the superior ramus of the ilium. This torsion causes compression along the upper side and tension along the underside of the ramus, both in a spiraling pattern towards the anterior part of the acetabulum. In extension the ilium transmits a larger amount of force through the anterior part of the acetabulum and thus cause compression stress along the anterior part of the iliac bone and tensile stress at angles to this.

DISCUSSION

In the complete evaluation of the stress distribution in the pelvis it is clear that the cortical bone plays a major part. The experimental indications that a

part of the actual load is transferred to the corticalis (Dietschi 1978). This does not mean that the interior of the bone is free of stress. In the long bones there will be a small change in the stress with movement as the forces are led through the bones regardless of position of the joints. Changes in the patterns will take place in the epiphysis as the major part of the bone will have altered stress pattern. In the pelvis, therefore, considerable changes in the force must be expected depending on the position in which the pelvis is loaded. As stated by Wolff (1892) and later confirmed by several authors, among others Pauwels and Kummer (1959), the trabecular pattern of the human skeleton is oriented according to the directions of the principal stresses and may be considered to represent the course of the stress trajectories. It should therefore be possible to analyze the trabecular pattern in the pelvis and from this to deduce the stress situation. As described the acetabulum is in the loaded phase over its entire joint surface where the bone distributes the pressure. The converging trabeculae around the joint may therefore be interpreted as representing compressive stresses.

With this as a basis the drawings in Figures 2, 3, and 4 have been constructed. These drawings represent the trabecular pattern as interpreted as compressive and tension stress trajectories. As will be seen compressive stresses are found along the outer rim of the iliac bone. Further back they run towards the sacroiliac joint. The pattern shown is a gothic-arch pattern similar to the one found in the femoral neck. According to Pauwels (1965) and Kummer (1959) this indicates a bending moment. The stress trajectories continue along the inferior aspect. This means that the posterior aspect of the acetabulum and the tuber may be related to a curved beam which is fastened at both ends and is loaded in compression on its concave side. This will cause a stress situation as shown in Figure 10. The

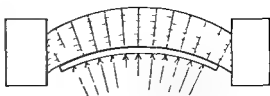


Figure 10 Stress pattern in a curved beam, loaded evenly along its concave surface

occurrence of spiraling compression and tension trabeculae at the base of the superior pubic ramus corresponds exactly to the stress distribution in a round bar loaded in torsion (Frost 1973). In the corpus ossis pubis the compression trabeculae arise from the symphysis in accordance with Pauwels' demonstration of the fact that the symphysis is loaded in compression during walking.

The significance of the special points, here indicated by the letters A through F, is more complicated to evaluate. The heavy structure at the sciatic notch would seem to indicate a reinforcement of the bone because of the convergence of the compression stresses at this point together with the effect of the bending moment which will be present during flexion of the hip. The star-shaped configuration of the trabeculae just below the acetabulum in Figure 4 complies well with stress concentration at this point indicating a forward bending moment. This is to be expected from the overall theoretical evaluation of the stresses given above. The thin spots have a different significance. The thin spot in the ala (point A) can be interpreted as representing an area with low stresses and with little bone needed to withstand them. The most interesting points are those marked B, E, and F. The configurations at these points have a striking likeness to repulsive singular points as described in textbooks on stress analysis (Pirard 1947, Wolf 1976). The presence and position of singular points cannot be predicted but must be confirmed by experiment. Singular points may be divided into repulsive and attractive points. Briefly, they may be described as points or areas where the stress has no distinct direction either because it is

nil or because it has the same value in all directions, it becomes "hydrostatic" Point C at the lower end of the acetabulum (Figure 2) is less clearly defined, but in some cases it also has a definite resemblance to a repulsive singular point Point D (Figure 4) clearly indicates a point of torsional stress where the interior of the bone is free of stress and the trabeculae wind around it in a spiraling fashion Point E must be seen as a repulsive singular point indicating an area of very low stress

The conclusion of the above would then be that the pelvic bones show a systematic pattern of trabeculae that corresponds well with the expected patterns of the theoretical stress trajectories as evaluated by an analysis of the shape of the bone and the forces working on it The patterns are much more complicated than in any other major bone

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MECHANICAL PROPERTY DISTRIBUTIONS IN THE CANCELLOUS BONE OF THE HUMAN PROXIMAL FEMUR

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Proximal femurs obtained at routine autopsy were sectioned into large numbers of 5 mm cubic specimens, in order to obtain detailed quantitative information about the spatial and directional variations of the material properties of the cancellous bone. Low strain rate compression tests were performed, evaluating the apparent elastic modulus and yield strength, in three perpendicular testing directions, for each cube. A computer contouring program was used to assemble the experimental data into smoothed distribution plots across sections of interest.

The results revealed stiffness and strength elevations/reductions which clearly correspond to roentgenographic features. Especially prominent stiffness elevations (160 to 400 percent above the overall cancellous bone average) were found in the regions traversed by the primary trabeculation system, although the modulus of the bone samples was substantially reduced when measured in directions other than those of habitual weight-bearing. Similar but less pronounced effects were observed for the arcuate trabeculation system. Conversely, Ward's triangle and the intertrochanteric regions exhibited significant (as much as 40 to 90 percent below average) stiffness and strength reductions.

There was close qualitative agreement between the stiffness and yield strength distributions for all sections examined. This phenomenon was found to be a corollary of the remarkably linear proportionality between the modulus and yield strength values for individual compression tests.

Key words: biomechanics, bone physiology, femur head, femur neck, stress, mechanical.

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transmission abnormalities associated structural anomalies in the proximal play a major role in conditions such as arthritis, osteoporosis, and idiopathic necrosis. Also, the degree of stability can be obtained by delivery of the stress appropriate portion of the proximal in the instance of fracture, fracture and implant insertion depends upon internal distribution of the material properties. Detailed information on the modulus variations in the proximal femur is also important in the context of implant design,

given the desirability of minimizing resorption and loosening at bone/cement and bone/porous implant interfaces. However, there has been relatively little effort expended toward systematic determination of the actual stiffness and strength variations, upon which the stress transmission patterns and points of fracture initiation depend.

Mathematical simulations of the internal stress distributions in the proximal femur, both with and without endoprostheses, have recently been undertaken in several laboratories (Andriacchi et al 1976, Brown &

Ferguson 1978, Harris et al 1978, McNiece et al 1976, Rybicki et al 1972, Scholten et al 1978, Valiappan et al 1977), using computer-based finite element stress analysis techniques. The accuracy of such mathematical models, unfortunately, can be no better than that of the material property distribution data upon which they are based. The present paper reports results of direct rheological tests aimed at cataloging spatial and directional variations of the mechanical properties of the cancellous bone in the human proximal femur.

There now exists a broad consensus that the stiffness and strength of cancellous bone are intimately dependent upon both the ash weight (or, void fraction) and the trabeculation pattern (Behrens et al 1974, Carter & Hayes 1977, Galante et al 1970, Lindahl 1976, McElhaney et al 1970, Pugh et al 1973, Schoenfeld et al 1974, Townsend et al 1975b). Because of the complex internal anatomy of the proximal femur, pronounced spatial and directional cancellous bone material property variations are to be expected. There have been studies aimed at cataloging stiffness variations in the distal femur/proximal tibia (Behrens et al 1974), and in the patella (Townsend et al 1975b), although in both cases the resolution of the spatial variations was somewhat limited due to the small number of sampling locations considered. For the proximal femur, however, the data are sparse and somewhat inconsistent. Hardinge (1949) in an early study of penetration resistance of femoral head

was able to identify a band of elevated hardness extending upward from the medial end of the inferior cortex of the femoral neck to the middle of the superior surface of the head. But Schoenfeld et al (1974), working with 3/16-inch diameter cylindrical specimens oriented parallel to the femoral neck, were unable to detect any significant correlation between specimen location and material properties. Harris et al (1978) have recently used an EMI scanner to map proximal femur stiffness, a technique which avoids tedious physical measurements

on individual samples. However this does not yield direct stiffness or strength information, and does not account for anisotropic (direction-dependent) properties of the cancellous bone. In the present study direct mechanical measurements are used to assess the stiffness and strength of individual cubic cancellous bone samples, each going successive uniaxial compression in three mutually perpendicular directions. A large number of samples is considered as to permit computer based average contour maps of section by section material property variations.

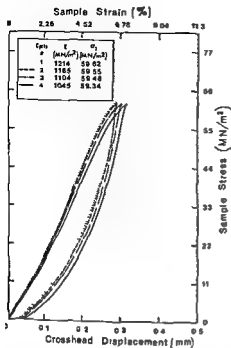
MATERIAL AND METHODS

Proximal femurs were removed at autopsy from donors who had no known disease, and who were under no treatment known to influence bone deposition or resorption with gross evidence of cartilage degeneration excluded from the study. The excised femurs were cleared of extra soft tissue, frozen and stored at -10°C until the mechanical testing.

After thawing the specimens were cut into a large number of side-by-side samples using a Unimat machining rig equipped with a circular saw blade. The blade kept thoroughly lubricated with oil and run at low speed (about 500 rev/min) to avoid excessive heating and friction on the cutting groove. The sample cubes had edge lengths of 5 mm and were all oriented with faces in the superior-inferior, medial-lateral and anterior-posterior directions. Approximately 1200 side-by-side samples were obtained from each proximal specimen but only about 800 of the 1200 were suitable for mechanical testing. The sample dimensions were measured with a micrometer.

The sample cubes were subjected to uniaxial compression tests using an Instron Model 1122 Universal Testing Machine at a constant crosshead speed of 0.05 mm/min to obtain a stress-strain curve (Figure 1) for the material. The stress-strain curve was calculated from the force-deformation curve on a strip chart recorder.

For one femoral head the compression tests were continued past the inflection point of the load-deformation curve. The tests were stopped at the point where yielding was more



1 Stress strain behavior for a typical sample undergoing successive compression to the incipient yield point. The modulus (derived from manual measurements of the linear portion of the stress strain curve) were found to decrease only slightly (< 5 percent) test to test, indicating that no significant material compromise was involved.

ined by operator judgment. This technique provided a reasonable estimate of the yield stress, but of course held the potential risk of missing the specimen's structural integrity subsequent loadings in the other two directions. However, multiple cycles to the incipient yield point in the same direction revealed successive modulus values differed by no more than 5 percent (Figure 1) if the tests were performed, indicating that serious material compromise could be avoided.

■ In undertaking large numbers of compression tests, other artifacts associated with the usual testing protocol were studied. The strain rate (Figure 2) was found to have no appreciable influence on sample stiffness within the range of measurements (strain rates of 0.0001 to 0.01 s⁻¹). The end effects associated with the width-to-length ratio of our cubic samples estimated from finite-element stress analyses, the program of Brown & Ferguson (1978). Results of the computer simulation showed the vicinity of the platens the stress field

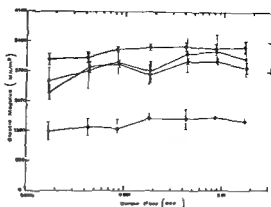


Figure 2 The influence of compressive strain rate upon the measured elastic modulus. For the samples tested, there was no significant effect over a strain rate range from 0.0001 to 0.01 s⁻¹. The tests were performed in random sequence, the bars denoting the standard deviation of measured values at each strain rate.

departed appreciably from one of uniaxial compression and that the gross load-to-deformation ratio (and hence the apparent elastic modulus) of our cubic samples was 5.27 percent higher than that which would have been observed with a conventional specimen test geometry. This stiffening artifact was readily compensated for in the computer algorithm which was used to extract modulus values from the raw experimental data. To assemble the large number of cube sample measurements into catalogues of the spatial variations of the mechanical properties within a given proximal femur a computer-based contour plotting algorithm* was modified to accept modulus and yield strength data for many points located within irregularly shaped femur sections.

RESULTS

Graphical representation of the complete experimental data in terms of two-dimensional section maps is somewhat cumbersome, as a total of 504 maps would be necessary. The salient property distribution phenomena can be appreciated, however, from the abridged series of five maps discussed below. Three-

*Program PMRC, developed by the Pittsburgh Mining Research Center of the US Bureau of Mines.

Ferguson 1978, Harris et al 1978, McNiece et al 1976, Rybicki et al 1972, Scholten et al 1978, Vahappan et al 1977) using computer-based finite element stress analysis techniques. The accuracy of such mathematical models, unfortunately, can be no better than that of the material property distribution data upon which they are based. The present paper reports results of direct rheological tests aimed at cataloging spatial and directional variations of the mechanical properties of the cancellous bone in the human proximal femur.

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on individual samples. However, this does not yield direct stiffness or strength information and does not account for anisotropic (direction-dependent) properties of the cancellous bone. In the present study, direct mechanical measurements are used to assess the stiffness and strength of cubic cancellous bone samples, each undergoing successive uniaxial compression in three mutually perpendicular directions. A large number of samples is considered as to permit computer-based stress contour maps of section-by-section material property variations.

MATERIAL AND METHODS

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After thawing, the specimens were cut into a large number of side-by-side samples, using a Unimat machine equipped with a circular saw blade. The blade was kept thoroughly lubricated with oil, and run at low speed (about 500 rev/min) to avoid excessive heating and friction. A cutting groove 1 mm deep was cut along the edge lengths of 5 mm and were all oriented with faces in the superior, medial, lateral and anterior-posterior directions. Approximately 1200 side-by-side samples were obtained from each proximal femur specimen but only about 800 of the cubes were suitable for mechanical testing. Sample dimensions were measured with a micrometer.

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For one femoral head the compression tests were continued past the inflection point of the load-deformation curve. The tests were stopped at the point where yielding was ex-

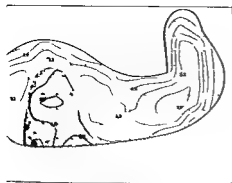
nal material property data for the have been recorded *in extensa* on r tape, available upon request from ors

distributions of mechanical properties a coronal midsection of a typical l femur are illustrated in Figure 3 . elastic modulus of sample cubes in the superior-inferior direction 3a), it is apparent that the primary ation family constitutes a stiffness versing the femoral head (shown on the contour map), with modulus n the range of 4800 to 6900 MN/m² eas of reduced stiffness are also dis- in the head region, one with a n stiffness value of about N/m² located superiorly and laterally i), the other with minimum stiffness 0 MN/m² located inferiorly and (point B) The highest cancellous ifness values, up to 9700 MN/m², und 16 occur just inside the medial ear the distal boundary of the section), and clearly correlate with the high isity area of that region (see Figure dulus values below 1400 MN/m² are ered in the area of Ward's triangle D) The secondary, or arcuate, ation system is identifiable as a (3400 to 5200 MN/m²) area of elevation curving superiorly and around Ward's triangle, and g downward into the middle of the chanteric region The most compliant the entire section was found to be centrally from the distal end of the system, and involved modulus values as 1000 MN/m² (point E) The us bone of the greater trochanter was atively compliant, and showed a mild "slope" (roughly 3500 MN/m²-cm) ially toward the muscle attachment Cubes from this section tested instead medial-lateral and anterior-posterior ns led to contour plots with basically me landmarks as those seen for r-inferior compression In general e their transverse stiffness values

were found to be somewhat lower (by 26 percent and 34 percent, respectively) than those measured with superior-inferior loading

It is interesting to compare the pattern of stiffness distribution with that of the yield strength (see Figure 3b) Test samples taken from weight-bearing trabecular system can sustain superior-inferior compression levels of as much as 310 MN/m² whereas those from non-weight-bearing regions in the head typically fail at stresses of from 120 MN/m² (point A) to 150 MN/m² (point B) Note that as is the case for stiffness the lowest values for yield strength occur not within the head but rather in the intertrochanteric region on either side (points D and E) of the distal extension of the tensile trabeculation system Examination of the strength pattern in this section for cubes loaded in the medial-lateral direction (see Figure 3c) reveals that bone in the primary trabeculation system consistently fails at transverse stress levels only 50 to 70 percent as high as those which can be safely sustained longitudinally (compare with Figure 3b) Also it is evident from the prominent strength elevation area (shown shaded) which runs horizontally through the central region of the head in Figure 3c that the secondary trabeculation system contributes substantially to the head's (limited) ability to sustain transverse stress elevations

Since the patterns of load transmission through the hip are inherently three-dimensional, it is also interesting to examine the material properties of other sections. Figure 4a depicts the superior-inferior test direction modulus distribution across a sagittal section located 35 mm lateral to the medial margin of the head A marked increase in stiffness from 3200 MN/m² to 9800 MN/m² can be observed from the upper to the lower part of the femoral neck Also, there is approximate anterior-to-posterior symmetry in the stiffness distribution for this section, with a central, posteriorly curving, high-stiffness ridge separating compliant regions located anteriorly (2800 MN/m²) and posteriorly (1900 MN/m²)



5a Superior-inferior elastic modulus E across a transverse section, 45 mm below superior margin of the head. The compressive load causes a surprisingly wide stiffness E (shown shaded), biased slightly toward the femur.



5b Roentgenogram of the corresponding transverse section.

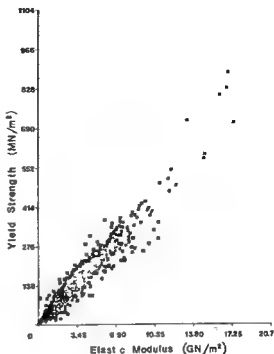


Figure 6 The relationship between the elastic modulus and incipient yield strength of the cancellous bone samples. This figure consisting of 1938 data points plotted by computer (646 cubic samples each tested in all three directions) demonstrates that the yield strength and stiffness values are remarkably proportional to one another regardless of the testing direction.

DISCUSSION

The techniques employed in this study yielded direct quantitative information on the distributions of stiffness and strength of cancellous bone of the human proximal femur. Data of this type are clearly necessary in order to take full advantage of new computer-based stress analysis techniques such as the finite element method. The assumption that the cancellous bone of the proximal femur is a homogeneous, isotropic material (Andriacchi et al 1976; Rybicki et al 1977; Valiappan et al 1977) need no longer be made. The results were generally good qualitative

similarity between the calculated property distributions and the corresponding trabeculation patterns (as shown in radiographs). This finding coupled with the quantitative agreement with other rheological studies of cancellous bone in the literature (see Table 1) indicates that the results of this study are reasonable.

The present investigation assumes that cancellous bone behaves as a continuum on the scale of the 5 mm cubic test samples. Since inter trabecular dimensions are of the order of 0.5 mm something like 10^2 marrow-to-bone discontinuities typically exist across our square testing sections. According to the criterion of Fung (1977) this represents about

Table 1 Rheological studies of cancellous bone

Investigator(s)	Specimen location	Strain rate (s^{-1})	Loading direction	Young's modulus (G)
Schoenfeld et al. (1974)	Femoral head	0.0044	Parallel to neck axis	1.2
Carter & Hayes (1977)	Tibial plateau	0.1	Superior inferior	1
Townsend et al. (1975b)	Patella	0.0007	Superior inferior	3.1
	Patella	0.0007	Anterior posterior	4.6
	Patella	0.0007	Medial lateral	3.9
Brown & Ferguson (1978)	Femoral head	0.004	Superior inferior	1.4
	Femoral head	0.004	Anterior posterior	2.2
	Femoral head	0.004	Medial lateral	2.3
Present Study	Proximal femur	0.004	Superior inferior	1.4
	Proximal femur	0.004	Medial lateral	2
	Proximal femur	0.004	Anterior posterior	1.9

the minimum sample size for which the continuum characterization is realistic. Thus, our material property distribution data are not directly applicable to the study of small-scale phenomena such as deformation or fracture on the level of individual trabeculae (Townsend et al. 1975a). However, our data do constitute reasonable and indeed necessary input for regional adaptations of non-continuous structural models such as that advanced by Pugh et al. (1973).

Although the present investigation is among the first to consider directional variations in the material properties, we recognize that the tabulation of Young's modulus values for three orthogonal test directions by no means constitutes a rigorous rheological description of an anisotropic elastic solid. Indeed, characterization of all the combinations of interaction between the nine elements (three normal and six shear) of the stress tensor and the nine analogous elements of the strain tensor requires a total of 81 influence coefficients. While it can readily be shown that only 21 of these coefficients are independent under normal circumstances (Lekhnitsky 1963), the number of tests theoretically necessary to fully describe the elastic behavior of hundreds of individual sample cubes is still staggering. But for practical purposes such as prosthesis design, mathematical modelling, or better

disease description, the present provides what appears to be a reasonable approximation to the salient aspects of proximal femur cancellous bone homogeneity and anisotropy.

CONCLUSIONS

Computer based assembly of modulus of yield strength data for the cancellous proximal femurs sectioned into large cubes of 5 mm cubes produces contour maps that agree reasonably with the conventional sectional x-rays. The method is a labor-intensive but does provide quantitative data at acceptable resolution of the spatial and directional material variations.

To a surprising degree the stiffness of yield strength values at a given point in the proximal femur were found to be proportional to one another regardless of degree of anisotropy at the point under consideration. Cancellous bone in the primary trabecular system, when tested in longitudinal tension, typically exhibited stiffness 160 to 400 percent above the proximal femur average. The stiffness of these same primary samples, when tested instead in compression, was only about 50 percent

that observed for the longitudinal stiffness elevations (especially under compression) were also evident in the oral head regions traversed by the trabecular system, but the magnitude of the stiffness elevation was considerably less pronounced than that observed for the primary trabeculation system. Other views (sagittal and horizontal) showed that the primary trabeculation increases appreciably in stiffness with increasing moderately in cross-sectional area as the joint load is transferred distally from the articular surface toward the medial aspect of the neck.

ACKNOWLEDGMENTS

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MECHANICAL STRENGTH OF McLAUGHLIN HIP NAIL-PLATES MANUFACTURED FROM 316 LVM STAINLESS STEEL

Mechanical Study of Unstable Trochanteric Fractures V

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Mechanical testing of McLaughlin hip nail plates manufactured from 316 LVM stainless steel was performed

The mode of failure is described and the results are compared with previous tests of McLaughlin implants manufactured from Cobalt-Chromium-Molybdenum alloy. As there was no significant difference between these two products as regards the basic mechanical problem of failure of the nail plate junction, it is recommended that the design be changed to make the implant suitable for internal fixation of unstable trochanteric fractures.

Key words: biomechanics, fracture fixation, femoral neck fractures, stress, mechanical

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In a previous paper (Jensen 1980) the mechanical strength, under static loading, of McLaughlin implants manufactured from Cobalt-Chromium-Molybdenum alloy was tested. From the experiments it was concluded that these implants were unsuitable for the internal fixation of unstable trochanteric fractures due to deformation and tearing of the nail-plate junction at very high loads.

Zimmer-USA has modified the weak nail-plate junction by increasing the thickness of the washer interposed between the top bolt and the back of the plate and besides that locked the top bolt with an additional centrally placed bolt with a left hand thread (Figure 1). The dimensions of the nail and the plate are basically the same as the Cobalt-Chromium-Molybdenum

The purpose of the present investigation was to examine the mode of failure of this modification of the McLaughlin implant, manufactured from 316 LVM stainless steel, and to compare the results with those recently published regarding Cobalt-Chromium-Molybdenum implants (Jensen 1980).

MATERIALS AND METHODS

The experiments were performed on McLaughlin hip nail-plates manufactured from 316 LVM stainless steel having angles and lengths as listed in Table 1. Five-hole plates were used in all cases (Catalogue numbers 2407-05, 96-00-XX, Zimmer USA International). The moment arm about the intersection between the back of the plate and the centre line of the nail was kept constant (-41.4 mm).

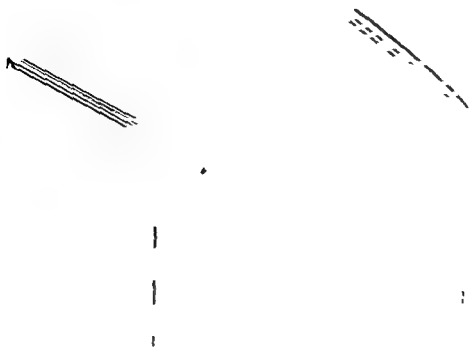


Figure 1 The components of the McLaughlin implant manufactured from 316 LVM stainless steel and after assembly

Static mechanical load testing was performed on the McLaughlin implants mounted with an inclination of 11° in the vertical with simultaneous readings of the applied load, the deflection of the nail tip, the elongation of the moment arm and the surface strain of the nail 25 mm from the junction and of the plate 5 mm from the base of the curved extension. A detailed description of the experimental arrangement has been published recently (Jensen 1980).

Five experiments were performed for six differently angled nail plates. For each set curves were calculated and load-deflection and load strain diagrams were constructed.

The yield points, where the metal underwent permanent plastic deformation, were determined from all diagrams as the point where the straight part of the graph is transformed into a curved line.

In accordance with equations presented in a previous paper (Jensen 1980) the bending

Table 1 Applied nail plate angles, moment arms and nail lengths of McLaughlin implants manufactured from 316 LVM stainless steel

Nail-plate angle	Moment arm about intersection	Moment arm about nail-plate junction	Nail length
			mm
degrees	mm	mm	
126°	41.4	51.1	74.9 (2.95")
132°	41.4	50.0	83.0 (3.27")
138°	41.4	48.7	94.6 (3.72")
150°	41.4	46.0	141.3 (5.56")

YIELD-POINTS			
126°	= 260 N	126°	= 670 N
132°	= 245 N	132°	= 680 N
138°	= 250 N	138°	= 650 N
150°	= 260 N	150°	= 615 N

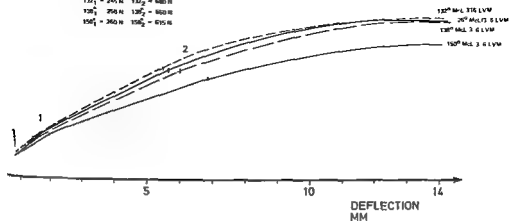


Figure 2 Load deflection diagrams for trifin McLaughlin hip nail-plates manufactured from 316 LVM steel

eld point about the nail-plate junction and strain gauge centre on the trifin nail were d, as well as the varus angulations at the field points

TS

ad-deflection diagrams for the entire McLaughlin hip nail-plates are illustrated in Figure 2. It is seen that two points were encountered for each

high yield point occurred at 660–680 implants with angles of 126°–138° red with 615 N for 150° nail-plates. In 3 the load-strain diagrams for the nails and the plates of different angles own. It is seen that the yield points for fin nails correspond fairly well with the yield points of the load-deflection ms and that the yield points for the

occur at slightly lower values. A yield point corresponding to bending plate could thus not be determined the load-deflection diagrams. The high points of the McLaughlin implants are caused by permanent plastic de- sion of the nail and the plate

YIELD-POINTS NAILS

126°	= 680 N
132°	= 680 N
138°	= 680 N
150°	= 600 N

YIELD-POINTS PLATES

126°	= 590 N
132°	= 570 N
138°	= 550 N
150°	= 530 N

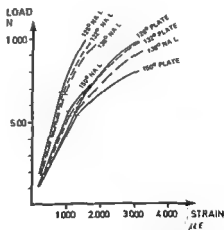


Figure 3 Load strain diagrams for trifin McLaughlin hip nail plates manufactured from 316 LVM stainless steel.

The bending moments about the strain gauge at the trifin nail 25 mm from the nail-plate junction were calculated as shown in Table 2. It was demonstrated that the bending

Table 2 Calculated bending moments about strain gauge centre on trypsin h.p. nail plate implants

Nail plate angle degrees	Elongation of moment arm MA mm	Yield load J N	Bending moment (316 LVM) M_b	(Co-Cr) M_b
126°	6.09	680	26.1 Nm	219 N
132°	7.16	680	27.3 Nm	241 N
138°	9.87	660	28.6 Nm	251 N
150°	16.32	560	28.7 Nm	281 N

The bending moments for the Cobalt-Chromium Molybdenum implants are taken from a previous (Jensen 1980).

The yield loads are determined from Figure 2

moment at the yield point increased with the nail plate angle from about 26 Nm to about 29 Nm. The comparative values for Cobalt-Chromium Molybdenum implants were 22 to 28 Nm.

The low yield points in McLaughlin 316 LVM stainless steel implants were calculated to be 245–260 N (Figure 2) and were not significantly related to the nail plate angle.

The low yield point was in all cases caused by failure of the nail plate junction. The small knobs of the plate portion became slightly flattened at the lower contact point as well as at the corresponding point on the base of the nail. Furthermore the top bolt bent successively as demonstrated in Figure 4. The thin central bolt also bent accordingly and frequently made the disassembly of the

implant very difficult. The interposed did not deform macroscopically.

The bending moments causing deformation of the nail-plate calculated to be 12.5–13.6 Nm, of the nail plate angle. The figures for Cobalt-Chromium Molybdenum implants were 11.4–13.3 Nm.

The various dislocations of the nail encountered at the two yield points calculated. As shown in Table 1 a angulation of 2° corresponds to a deformation and thereby loosening of nail plate junction. A further bending about 4°–5° takes place before the nail and the plate start bending. The dislocation involved in the bending of nail plate junction as well as the nail plate was calculated to be 6° 7' corresponding to a loading of less than 4 N. Table 3 the comparative values for Cobalt-Chromium Molybdenum implants are listed. It is seen that the various dislocations caused by bending of the nail-plate and the nail and the plate was about higher in these implants, the corresponding loads being 590–640 N.

DISCUSSION

The McLaughlin h.p. nail plate, introduced in 1947 (McLaughlin 1947)

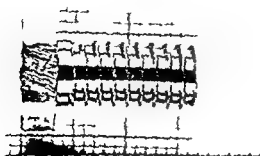


Figure 4 Top bolt bent after completion of testing

e 3 Calculations of the varus angulation in hip implants during mechanical loading

ail plate angle	β	Nail length L_N	Deflection e_1	β_1	Varus angula- tion $\beta - \beta_1$	Deflection e_2	β_2	Varus angula- tion $\beta - \beta_2$	Varus angula- tion $\beta - \beta_3$
deg	deg	mm	mm	deg		mm	deg		
126°	47°	74.9	1.60	45.2	18°	5.65	41.0	6.0°	
132°	53°	83.0	1.50	51.3	17°	5.50	47.1	5.9°	
138°	59°	94.6	1.55	57.2	18°	6.00	52.5	6.5°	
150°	71°	141.3	1.95	68.7	23°	6.85	52.5	7.2°	
126°		74.4	1.20		13°	7.40		7.8°	12.8°
132°		82.6	1.05		12°	7.10		7.6°	11.1°
138°		94.0	1.25		15°	7.40		7.9°	11.4°
150°		140.7	1.20		15°	4.55		5.1°	7.4°

1 angle = 79° The values stated for Cobalt-Chromium Molybdenum implants have been previously (Jensen 1980)

the most widely used device for fixation of trochanteric fractures, in many reports of failures at the nail-plate

5 McLaughlin & Garcia presented a revision of the original device. The top bolt was considered unreliable as a result of loosening of the top bolt had been

The loosening was thought to be due to unwinding of the top bolt. It was recommended that the nail and plate be assembled with the aid of a nut with a locking stud giving a higher torque

The present series 316 LVM stainless steel plates (Zimmer-USA International) were tested. The basic idea of this device is in accordance with the modifications of McLaughlin & Garcia (1955) as unwinding is prevented by an additional top bolt with a different thread. Moreover, the washer interface between the top bolt and the back of the plate is fairly thick.

316 LVM stainless steel implants did not seem to be significantly stronger than Cobalt-Chromium-Molybdenum devices (Jensen 1980), although the bending moments required to bring about failure were about 10% higher. The overwhelming mechanical problem was once again failure of

the nail-plate junction. Bending of the top bolt was the most illustrative finding and the yield load was determined to be less than 260 N. The basic problem is fairly similar for the 316 LVM stainless steel and the Cobalt-Chromium-Molybdenum alloy implants, as the design of the curved extension of the plate and the base of the nail are almost identical. The curved extension of the plate is hemispherical in shape and equipped with small knobs to prevent rotational instability. The base of the trochanteric nail is planar and equipped correspondingly with small notches for rotational stability. The dimensions of these two surfaces involves a total area of contact of less than one third of a square centimeter, even if they fit together perfectly. As this is not the case, due to differences in geometry, all the forces are concentrated to a very small area leading to the permanent deformations described and thereby loosening of the nail-plate junction. The loads required to bring about this loosening were as low as about 260 N. At this load the material starts undergoing deformation hardening and the area of contact is increased because of the deformation. The result of this is a certain amount of loosening, but the nail-plate junction is becoming stronger making further loading

and thereby determination of the yield point for the nail and plate possible. A disadvantage of the deformation hardening is, however, that the deformed areas become more susceptible to corrosion.

As the hip joint load during normal level walking is at least three to five times the body weight (Paul 1976, Rydell 1966) loosening of the nail-plate junction and thereby varus dislocation of the fracture is to be expected in every case in which the implant alone transmits the entire load from the hip joint to the femoral shaft. This is in principle the case in unstable trochanteric fractures, and consequently McLaughlin implants cannot be recommended for the internal fixation of these fractures, whether the implants are manufactured from 316 LVM stainless steel or from Cobalt-Chromium-Molybdenum alloy. A re-design of the nail-plate junction is thus needed in order to provide sufficient mechanical strength to allow full weight-bearing of the immediate rehabilitation after fracture fixation.

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OSTEOCHONDRITIS OCCURRING AT MULTIPLE SITES

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to the aetiology of coxa plana is discussed

Key words: coxa plana, Kohler's disease, Legg-Calvé-Perthes' disease, osteochondritis, patella

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observations of generalized growth abnormalities in cases of coxa plana (Burwell 1978b, Harrison et al 1976) have led to the conclusion that this condition is not simply a localized manifestation of avascularity (Burwell et al 1974, Sanchis et al 1973, Burwell & Ráliš 1974, Zahur & Freeman 1974, Fisher 1972, Wynne-Davies & Burwell 1978).

Several authors have noted children with osteochondritis juvenalis affecting several sites. Burwell (1978) gives five case reports of children with coxa plana followed by osteochondritis of the patella.

Recognition of this connection supports the concept of generalized abnormality in Legg-Calvé-Perthes' disease, and may enable diagnosis of osteochondritis at a site.

REPORTS

Case 1 DOB 25.1.64 First born. This child was referred at the age of 8 months because the left leg was shorter. Examination revealed some reduction of abduction and rotation, and X-rays demonstrated that

the ossific nucleus of the femoral head on the left side had not appeared whereas that on the right was well formed (Figure 1). However the acetabulum was well developed and there was no suggestion of dislocation.

An expectant policy was pursued but the ossific nucleus of the femoral head did not appear until 30 months and was then fragmented. After a protracted course this hip recovered well both clinically and radiologically (Figures 2 and 3). Although the child had no problems with the right hip, review of the radiographs showed changes of coxa plana in that hip, part head involvement only (Catterall (1971) Group One). Not surprisingly, this hip did well radiologically.

In January 1977, at routine follow-up, the boy complained of pains in the left knee and both heels. Examination confirmed tenderness at the upper pole of the patella with retropatellar crepitus. There was also tenderness in both heels. X-rays showed changes consistent with osteochondritis of the upper poles of both patellae, more marked on the left (Figures 4 and 5). These symptoms gradually settled with non-specific measures, although the patient is not able to participate in sport.

Case 2

MS Male DOB 23.6.69 This boy presented at the age of 6 with pain, lump and limitation of movement in the left hip. Radiographs demonstrated coxa plana with whole head involve-

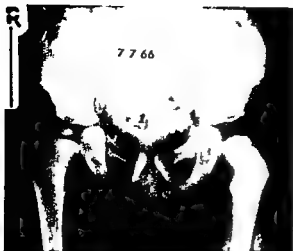


Figure 1 Case 1 Pelvic radiograph at 6 months

ment and the child was treated with crutches and a Snyder sling. He improved symptomatically but the X-ray changes progressed and then stabilized in the expected manner (Figures 6 and 7). The sling was withdrawn when the ossific nucleus was



Figures 2 and 3 Case 1 Pelvic radiographs at 2 years 5 months and at 11 years



Figure 4 Case 1 Radiograph of both knees.

seen to be consolidating when the child was 5 years and 5 months old and he made clinical improvement.

In June 1978 the patient twisted his ankle. The X-rays as well as revealing a chondral fracture of the lateral tibia showed collapse and sclerosis of the tibia (Kohler's disease). Radiographs of the foot showed similar but less advanced changes. Both before injury and after it had a foot was asymptomatic. At this time the bone age was between 5 and 6 (according to atlas of Greulich & Pyle 1977). Chronological age was 9.

Case 3

JH Female DOB 21/11/46. Presented at the age of 6 with a history of pain in the left thigh and limping. Examination revealed 2 cm of shortening of the left leg and adductor spasm. X-rays showed coxa plana but also established osteochondritis. The child was treated in an abduction frame for 1 year then discharged.



Figure 5 Case 1 Lateral radiograph of the hip



Case 2 Pelvic X ray at 8 years 7

relieving caliper. Progress was satisfactory but he was lost to follow up.

Case 3 DOB 6 5 67 This child presented at the age of 17 months with a 3 month history of pain in the left hip. He was otherwise normal and had no limp at 12 months. Clinical examination revealed limitation of internal rotation and abduction of the hip and radiographs confirmed the diagnosis. He was treated with a weight relieving cast for 1 year. Following this, his symptoms subsided and he had no further pain. At the age of 11 he presented with pain in both hips and a clinical diagnosis of Sever's disease was made. He continues to have intermittent com-

Case 4 DOB 26 1 67 This child presented at the age of 18 months with a left limp but no restriction of



Case 2 Pelvic X ray at 9 years 1



Figure 8 Case (a) Radiograph of right foot. (b) Radiograph of left foot

plaints. X-rays revealed coxa plana changes. He was treated initially by traction and then with a Snyder sling. Over the course of 3 years the symptoms subsided and the X-ray appearance resolved.

In August 1976 he was referred with pain and tenderness in the left heel. A clinical diagnosis of Sever's disease was made and he was treated with a heel raise. The symptoms resolved over 6 months.

DISCUSSION

Osteochondritis occurring at more than one site has previously been reported but almost all cases have been symptomatic at only one site the other being discovered by skeletal survey.

Blencoe (1924) described a case of coincident coxa plana and osteochondritis of the navicular. Lane (1924) described two cases with similar dual affections. Ponseti (1956) described two cases of coxa plana with asymptomatic navicular changes and also noted abnormalities of acetabular ossification. Wolf (1950) reported seven cases of osteochondritis of the lower pole of the patella (Sinding-Larsen-Johannson disorder). Also present in several of these were symptoms from the tibial apophysis (Osgood-Schlatter disorder). Two series of coxa plana patients subjected to radiographic survey showed a total incidence of multiple disorders in 60 out of 200 cases. Bilateral hip involvement

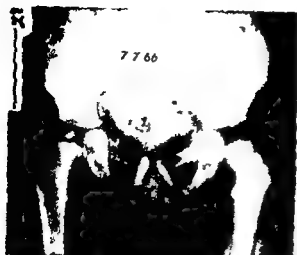


Figure 1 Case 1 Pelvic radiograph at 6 months

ment and the child was treated with crutches and a Cast. The Cast was removed and the child was allowed to walk. The Cast was withdrawn when the ossific nucleus was

Figure 4 Case 1 Radiograph of tibiae, both knees.

seen to be consolidating when the child was 2 years and 5 months old and clinical improvement.

In June 1978, the patient underwent surgery for a chondral fracture of the lateral femoral condyle. Radiographs of the knee showed collapse and sclerosis of the bone (Kohler's disease). Radiographs of the hip showed similar but less advanced changes. Both before injury and after it had a foot was asymptomatic. At this time the bone age was between 5 and 6 years (Greulich & Pyle 1957) chronological age was 9.



Figures 2 and 3 Case 1 Pelvic radiographs at 2 years 5 months and at 11 years

Case 3

JH Female DOB 21/1/41. Presented at the age of 6 with a history of pain in the left thigh and hip. Examination revealed 2 cm of hip and adductor spasm. X-ray showed coxa plana but also established osteochondritis. The child was treated with abduction frame for 1 year, then surgery.



Figure 5 Case 1 Lateral radiograph of femur

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HAEMATOGENOUS OSTEOMYELITIS AND SEPTIC ARTHRITIS IN CHILDHOOD

Long-term Review and Follow-up

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Seventy-three children, who were admitted to hospital during the period 1965-1976 with osteomyelitis or septic arthritis, were included in a retrospective study as well as a clinical and radiological follow-up. Ten

disease showed that none had any complaints or invalidity. However, one patient with neonatal septic arthritis presented severe dysplasia and subluxation of the hip and four children with osteomyelitis had severe, but asymptomatic, radiological changes.

Key words: children, follow-up, osteomyelitis, septic arthritis

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With the development of modern treatment, skeletal infections in children often have a prolonged course and lead in some cases to invalidity (Howard et al 1975, Dich et al 1975, Howard et al 1976). A retrospective investigation was carried out to clarify the clinical, radiological, and therapeutic aspects. To evaluate the long-term prognosis, a clinical and radiological follow-up study was carried out.

RESULTS

During the period 1965-1976 73 children (39 boys and 34 girls) under the age of 15 years were

admitted to the Departments of Paediatrics and Orthopaedic Surgery at Glostrup and Gentofte Hospitals with acute haematogenous osteomyelitis or septic arthritis.

At least two of the following diagnostic criteria were met: (1) Localized tenderness, redness, swelling or reduced mobility, (2) Pus aspirated from bones or joints, (3) Growth of pathogenic bacteria from blood culture, and (4) radiological manifestations of osteomyelitis or septic arthritis. Children with radiological signs of both osteomyelitis and septic arthritis were primarily assigned the former diagnosis. The distribution according to age, sex and diagnosis is shown in Figure 1. Fifty-eight children had osteomyelitis, and of these 10 had complicating septic arthritis. Fifteen children suffered from only septic arthritis. Two children suffered from diseases associated

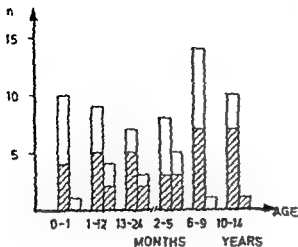


Figure 1 Seventy-three children with acute haematogenous osteomyelitis and septic arthritis

Left column osteomyelitis

Right column septic arthritis

□ Girls

▨ Boys

with an increased tendency to bacterial infections chronic granulomatous disease and immunodeficiency, respectively. Shortly before the development of the disease, umbilical artery catheterization had been performed in three infants (Knudsen & Petersen 1977).

Table 1 Radiographical changes in 47 infectious foci in 43 patients with acute osteomyelitis

Grade of severity*	Initially	At follow-up		
		n	None	Slight Severe
0	1	1		
1	2	2		
2	25	17	7	1
3	4	3		1
4	15	6	7	2
Total	47	29	14	4

*Grade 0 no changes. Grade 1 soft tissue

swelling. Grade 2 destruction or involucrum

for more than 60 days.

Grade 3 more pronounced bone destruction

result in late recurrence or arthritis

In 39 out of 44 children with osteomyelitis in 14 out of 15 with septic arthritis, treatment was initiated within 1 week after the first symptoms. In six children symptoms had been present for more than 4 weeks prior to initiation of adequate treatment. The treatment cases consisted of immobilizing the affected limb. In seven children with osteomyelitis the bone was drilled for drainage of pus while bone was performed once or more in 20 cases of arthritis, closed drainage was not performed. Antibiotic therapy varied greatly from parenteral to another and throughout the follow-up. Forty-seven of the 73 children were treated with penicillinase-resistant penicillins or fusidic acid. Sixteen were exclusively with benzylpenicillin, six with ampicillin alone and three with combinations of antibiotics. Initially intravenous therapy was given parenterally in 40 patients in only 10 for more than 2 weeks. The duration of antibiotic therapy was more than 3 weeks and more than 6 weeks in 34 out of the 73 children.

METHODS

Radiographs were repeated during the recovery period. Blood cultures (10 ml) and cultures of aspirates from osteomyelitis were performed in only half of the cases. Cultures of joint fluid were performed in 40 patients. Culture for TB, candida and anaerobes were not performed routinely. In 10 patients antibiotic therapy had been initiated and a culture was made.

All data concerning clinical, bacteriological and therapeutic conditions were reviewed. In 1977, the children were summoned to a follow-up examination. A questionnaire was completed and was evaluated on the basis of data from the records. Ten of the children had been examined (Strandgaard & Elton). Roentgenograms were reassessed by the authors (ME). The initial radiographs were classified into five grades in order to express the severity as well as the duration of the changes (Table 1). The radiographs at follow-up were classified into three grades: slight changes being defined as a slight structure with slightly irregular bone at the previous site of infection, and moderate changes being defined as abnormal bone structure more pronounced bone destruction and result in late recurrence or arthritis.

pects

ence of both osteomyelitis and ritis was highest during the first 2 e. Of the 58 cases of osteomyelitis d in the neonatal period and 26 first 2 years of life. Of the 15 cases rthritis 8 occurred before the age of gure 1).

ost frequent sites of the os- : foci were the metaphyses of the s $\frac{1}{2}$ occurring in the lower and upper extremity. Septic arthritis d in the weight-bearing joints in es.

ldren had multiple osteomyelitic one child septic arthritis in more ont.

ms such as swelling, warmth, redness ed mobility were more frequent in rthritis than in osteomyelitis, but in e cases the clinical symptoms were

y data

the children with osteomyelitis and of those with arthritis, the e sedimentation rate was more than

It was difficult to evaluate the od count (WBC) and the number of lic granulocytes because of the pro- variation due to age, but it was le that about $\frac{1}{3}$ of the children had a ss than 10,000 per μ l.

ogy

e blood culture was obtained in 14 l of the cases. Aspirates from os- ic foci gave growth in 10 out of 25 l joint aspirates in septic arthritis in 15 cases.

aureus was the causative organism es of osteomyelitis and three cases of rthritis. Ten of the strains were to penicillin. Betahaemolytic

streptococci were isolated in three cases of osteomyelitis and two cases of septic arthritis. *H. influenzae* was isolated in three cases of osteomyelitis and one case of septic arthritis.

Radiological examination

Thirty-five out of 58 children with osteomyelitis had normal roentgenograms at the time of diagnosis irrespective of the duration of disease. Eight of these developed radiological changes within 7 days, 10 within 14 days, and another 11 within 28 days after the first symptom. In two children roentgenographic changes were not observed until after 28 days and four patients developed no radiological changes at all.

In Table 1 the initial changes in 47 osteomyelitic foci in the 43 patients included in the follow up study are classified according to degree of severity. In patients with septic arthritis no initial changes or only very slight ones were observed (Table 2).

Course

It appears from Figure 2 that 15 children with osteomyelitis had symptoms for more than 3 months while all those with septic arthritis no longer had symptoms by that time. Figure 3 shows the cumulative cure rate after initiation of treatment in 19 children.

Table 2 Radiographical changes in 13 infectious foci in 13 patients with septic arthritis

Initially	At follow up			
	Grade of severity*	None	Slight	Severe
	0	2		
	1	8	1	1
	2	3		
	3	0		
	4	0		
Total	13	11	1	1

*See Table 1

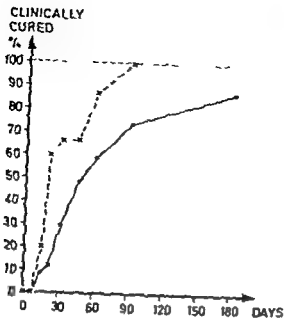


Figure 2 The cumulative cure rate after the first symptom.

● — ● Osteomyelitis
x - - x Septic arthritis

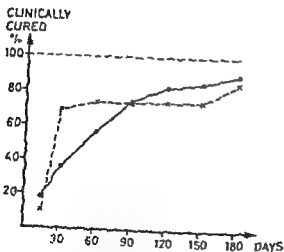


Figure 3 The cumulative cure rate after initiation of treatment for osteomyelitis

x - - x Nineteen children treated within 7 days with a penicillinase-resistant penicillin.
● — ● Thirty-nine children not treated within 7 days with a penicillinase-resistant penicillin.

with osteomyelitis who were treated 7 days after the first symptom with penicillinase-resistant penicillin compared with 39 children with osteomyelitis who did not start treatment with penicillinase-resistant penicillin initially. After 30 days the cure rates of the two groups were 68 per cent (19 out of 28) and 41 per cent (14 out of 34) respectively. This difference is significant ($\chi^2 = 5.7$, $0.01 < P < 0.02$). When separately neither treatment with penicillinase-resistant penicillin ($\chi^2 = 2.5$, $0.1 < P < 0.2$) nor initial treatment with penicillinase-resistant penicillin ($0.05 < P < 0.1$) improved the cure rates after 30 days treatment significantly.

In five children the osteomyelitis recurred. One recurrence occurred 5 years after the primary attack. One child had two recurrences of osteomyelitis in one leg over a period of 2 years. There was one case of chronic osteomyelitis with sequestrum formation 3 to 12 months after initial treatment. In four of the five cases, the treatment was with tetracycline only.

Follow-up examination

One child with immunodeficiency died from meningitis. None of the 69 children were evaluated had any complications. In two of the previous cases the affected leg was found to be longer than the other leg and in two arthritic cases a slight reduction in range of motion ($< 10^\circ$) was observed in the joint.

Table 1 shows the radiological findings in 43 children with 47 osteomyelitis. Twenty-nine of the infections had healed completely. In one of these cases the infection had been present earlier. In two patients with mild changes at follow-up, five out of seven with mild changes at follow-up had insignificant bone deformities and scars at the site of the primary infection. In one child slight calcification of soft tissue was found, but no bone deformity. Five out of seven patients with moderate changes at follow-up had bone deformities of grade 4 presented slight bone deformities.

no of these sequestration was present in the acute phase. These two patients had significant bone deformities only, i.e., osteosarcoma at the site of the previous joint. The first (initially grade 2) had osteosarcoma of the distal part of the fibula with osteosarcoma to the tibia. The second (initially grade 3) had coxa vara and irregular bone and deformity of the femoral neck and (initially grade 4) had narrowing of the intervertebral disc (L IV). The last (initially grade 4) had deformity of the shaft of the femur and genu valgum.

Table I shows the results in the 13 children with arthritis. In 11 the lesions had healed completely, one patient presented osteosarcoma, i.e., an accentuated patellar centre. One patient had osteosarcoma from a neonatal septic arthritis of the hip joint following catheterization of the femoral artery. The initial radiological changes were accumulation of fluid in the joint, slight lateral dislocation of the head of the femur. *Staph aureus* was isolated from the joint and the initial treatment was lincomycin for 4 weeks. The effect was favourable and clinical and radiological routine check-up at the age of 9 years was normal. Follow-up at the age of 11 years showed a small upper femoral osteosarcoma, subluxation of the femoral head, osteosarcoma of the acetabulum. The child died normally.

DISCUSSION

Joint infections in children may be localized and result in lasting invalidity. The prognosis is worse for septic arthritis, in particular if associated with osteomyelitis (Cole et al. 1975, Morrey et al. 1975, Morrey & Peterson 1975) or if the hip joint is affected (Cole et al. 1975, Morrey et al. 1975, Morrey & Peterson 1975). The diagnosis and therapy are of crucial importance for the prognosis (Cole et al. 1975, Morrey et al. 1975, Morrey & Peterson 1975, Nade et al. 1974, Nade 1974a, b).

It may sometimes be difficult to establish the diagnosis, especially in the newborn. Often the only symptom may be that the infant does not move the affected limb. In older children the symptoms of arthritis can be mistaken for rheumatoid arthritis or other types of arthritis. Therefore, puncture with aspiration and examination of joint fluid, i.e., microscopy, culturing and total leucocyte count, are mandatory whenever infection is suspected. Scintigraphy of the bone is of value for an early diagnosis (Treves et al. 1976).

The causative organism in osteomyelitis is most frequently *Staph aureus* and, in rare cases, streptococci (Dich et al. 1975, Morrey & Peterson 1975, Nade et al. 1974, Nade 1974a, b, Rhodes 1975). The most common causative organisms in septic arthritis are *Staph aureus* or *H influenzae* (Cole et al. 1975, Howard et al. 1976, Morrey et al. 1975, Nade et al. 1974, Nade 1975, Rhodes 1975). Of the *Staph aureus* strains 65-90 per cent were penicillin-resistant (Cole et al. 1975, Forsell 1974, Morrey et al. 1975, Morrey & Peterson 1975, Nade et al. 1974, Nade 1974a, b).

The initial treatment in osteomyelitis should be a combination of methicillin or cloxacillin and benzylpenicillin and, in arthritis, a combination of methicillin or cloxacillin and ampicillin (Cole et al. 1975, Nade et al. 1974, Nade 1974a, b, Nade 1975). Initially parenteral therapy should always be chosen (Cole et al. 1975, Dich et al. 1975, Morrey et al. 1975, Morrey et al. 1976, Nade 1974a, b, Rhodes 1975). The duration of treatment recommended varies somewhat, some continue for 6 weeks after stabilization of the clinical condition and normalization of temperature (Cole et al. 1975), others are guided by the ESR and the course (Nade 1974 a, b, Nade 1975, Rhodes 1975). Intra-articular administration of antibiotics (Morrey et al. 1975) may not be necessary, since a sufficient concentration of antibiotics in the joint will be obtained by parenteral administration (Tetzlaff et al. 1978).

Even though 25 per cent of the children with osteomyelitis in our study were ill for more than 3 months, and five had recurrences or developed chronic osteomyelitis, the follow-up showed that the long-term prognosis was good, as none of the children had any complaints or invalidity. This occurred even though the principles of treatment were less radical than those described. Even in some cases with prolonged bone destruction and sequestration, healing took place without severe radiological sequelae. However, in four children the follow-up examination disclosed radiological changes which in the future might cause arthrosis (Howard et al 1976) or late recurrence. The follow-up revealed one case with severe radiological changes of the hip joint after a neonatal septic arthritis following catheterization of the umbilical artery. An early arthrotomy might have improved the course. Only a few studies on the long-term prognosis are available for comparison. Lindblad et al (1965) found that about 25 per cent of children with osteomyelitis in the neonatal period had severe sequelae.

In our study the importance of early therapy with effect on penicillin-resistant staphylococci is documented by a significantly increased number of children clinically cured within 30 days of this treatment, and also by the fact that four out of the five children with recurrent or chronic osteomyelitis had not received such treatment.

Many of the children presented a prolonged and occasionally a complicated course. Presumably, intensive treatment during the initial phase of the disease might shorten the course. We recommend the following treatment schedule:

- 1 Specimens for bacteriological examination to be obtained by blood culture and aspiration from joints or osteomyelitic foci.
- 2 Intravenous antibiotic therapy for the first week and, if the clinical results are good, therapy to be continued orally for at least 6 weeks. The following initial therapy is recommended. For osteomyelitis, benzylpenicillin 300 000–500 000 IU/kg/24

hours + methicillin 200 mg/kg/24 divided into six doses. For sepsis: ampicillin 200 mg/kg/24 hours + penicillin 200 mg/kg/24 hours divided into six. Treatment to be changed, if the following sensitivity tests:

3 Drainage of collections of pus from the bone, followed by primary debridement. Fenestration of the bone is preferred in the case of pathological structure. Repeated punctures in case of arthritis. Arthrotomy to be performed if indicated by the clinical course, and in case of septic coxitis.

4 Immobilization of the affected limb.

5 After the acute phase mobilization and rehabilitation to be initiated.

6 Clinical and radiological follow-up in their first months of life to be checked if they can walk normally and normally have developed.

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EFFECTS OF OXYTETRACYCLINE ON MINERALIZATION OF BONE IN YOUNG RATS

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The metabolism of minerals and collagen in young rats receiving oxytetracycline was studied by employing double-isotope techniques. The dosage of the antibiotic was adjusted to obtain plasma concentrations comparable with human therapeutic levels. Reduced mineralization and possibly increased resorption of bone were observed after oxytetracycline administration, whereas no effect on the rate of collagen synthesis could be detected.

Key words: calcification, calcium, collagen, ^{14}C -proline, phosphorus, plasma concentration, tetracyclines, strontium-85

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It has been previously shown that administration of the antibiotic oxytetracycline to young rats causes reduced mechanical strength of bone and skin (Engesaeter & Skar 1978) and interferes with the cross-linking of collagen (Engesaeter et al 1980). Several *in vivo* studies (Kaitila 1971, West & Storey 1971) have indicated that tetracyclines exert an effect on bone by inhibiting the mineralization. *In vitro* studies, however, have given confusing results (Bevelander et al 1961, Iwagawa et al 1961, Harris et al 1968, Anderson 1971).

The present study was undertaken to elucidate the *in vivo* effect of oxytetracycline on calcification of bone. The effect on mineralization was assayed by injection of strontium-85 into bones (Cohn & Lian 1967) and the rate of collagen synthesis by measuring ^{14}C hydroxyproline from ^{14}C -proline (Firschein 1969). The isotope measurements were supported by determinations of the content of calcium, phosphorus and collagen in the bones.

MATERIALS AND METHODS

Fifty outbred male Wistar/Ki/Mol SPF rats were used. At the start of the experiment the animals were 23 days old, weighing 33-37 g. They were kept five in each cage and fed water and Norwegian standard diet for rats (containing 0.9 per cent calcium and 0.7 per cent phosphorus) *ad libitum*. The rats were divided into two weight-matched groups of 20 animals, one oxytetracycline treated and the other control. Ten rats were killed at the beginning of the experiment to obtain origin values of bone size and composition.

The treated animals received 2.8 mg oxytetracycline (Terramycin® Intravenous, Pfizer) in 0.5 ml water as intraperitoneal injections every twelfth hour for 7 days. As the rats grew rapidly the dose in mg/kg/day was higher initially than at the end, in the middle of the period 74 mg/kg was given twice a day. The control rats received corresponding injections of the vehicle. Plasma concentrations of oxytetracycline were determined on the fifth day of medication by the paperdisc method of AB-biodysk (Stockholm, Sweden) (Jalling et al 1972).

Twenty-four hours before the rats were killed $5 \mu\text{Ci}$ carrier free strontium-85 chloride

(330 Ci/mmol) and 15 μ Ci L-(14 C)proline (285 mCi/mmol) (The Radiochemical Centre, Amersham) per 100 g body weight were injected intraperitoneally.

On the third and the seventh day of the medication 10 rats from each group were anaesthetized with ether and blood was collected by puncture of the aorta at the iliac bifurcation. The animals were then killed by exsanguination. Both femurs were immediately dissected free and the length measured (from the top of caput to the distal end of the medial condyle) with a sliding calipers (accuracy of ± 0.01 mm). Soft tissues, cartilages and epiphyses were removed. Both femora were then placed in acetone for 7 days with two changes of acetone and air dried at 35°C until constant weight (dry weight) was obtained. The bones were then hydrolyzed in 4 ml 6M HCl at 125°C for 18 hours.

As hydroxyproline is practically unique to collagen, quantitation of collagen was performed

proline to 14 C-hydroxyproline (Firschein 1969). Mineralization rate was assessed by measuring the content of strontium-85. The bone hydrolysates, containing both ^{85}Sr and ^{14}C , were first counted in a well counter (Auto-Gamma Scintillation Spectrometer, Packard Instr. Comp.) to determine the content of ^{85}Sr (gamma-emitter), without interference from ^{14}C (beta-emitter) (Firschein 1969). The counting efficiency for ^{85}Sr was found to be 26 per cent. Dowex 50W columns were used to separate ^{14}C -hydroxyproline from ^{14}C -proline, as described by Firschein (1969). In addition, these columns also retain ^{85}Sr (Firschein 1969). Every sample was, however, checked in the Auto-Gamma Scintillation Spectrometer to make sure no gamma-emitter was present, before the radioactivity of the isolated ^{14}C -hydroxyproline was assessed in a liquid scintillation counter (Nuclear Chicago Mark II) with Dilusolve[®] (Packard Instr. Corp.) as scintillation solution. Counting efficiency, determined by the two channel ratio method, was 70 per cent.

The concentrations of calcium and phosphorus in the hydrolysates were measured using a Bichromatic Analyzer (Abbott Laboratories, Diagnostic Division, USA). The Bichromatic Analyzer was also applied to measure serum concentrations of calcium, phosphorus and albumin. The kits used in the analyses were from the Abbott Laboratories (A-Gent Albumin and Calcium) and the Phosphorus Auto/Stat kit of Pierce Chemical Co. (Rockford, Illinois, USA).

The median with 25- and 75-fractiles was used to express the average and the dispersion of the

measured values. Statistical significance was evaluated by the Wilcoxon test for two groups and differences were considered significant if $P \leq 0.05$ (Dixon & Lentner 1975).

RESULTS

On the fifth day of medication the plasma concentrations of oxytetracycline measured two hours after administration were 15 (14–16) $\mu\text{g/ml}$, 6 hours after administration it was 2.6 (2.3–3.0) $\mu\text{g/ml}$, and 12 hours after administration less than 1 $\mu\text{g/ml}$.

The increase in the body weight of the antibiotic-treated rats was significantly greater than that of the controls (Figure 1). Figure 1 illustrates longitudinal growth of the femur. The bones of the animals receiving oxytetracycline were significantly shorter than those of controls on both the third and seventh day of medication. Corresponding reductions were revealed in the cortex thickness and the diameters in the middle of the diaphyses. At the end of the experiment the dry weight of the femurs was found to be

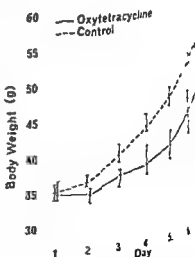
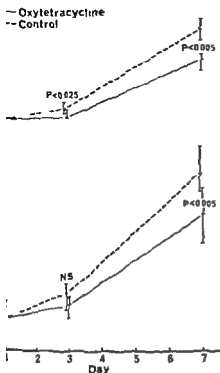


Figure 1 Body weight of the antibiotic-treated and the control rats (median with 75-fractiles)



Length of right femur (above) and dry of both femurs (below) of the oxytetracycline-treated and the control rats with 25- and 75 fractures)

less in the oxytetracycline-treated than in the controls (Figure 2). Biochemical analyses revealed corresponding differences. On the seventh day of medication the content of calcium and phosphorus in the bones of antibiotic-treated rats was significantly reduced (22 and 23 per cent, respectively) compared with controls, while the reduction in collagen content was 10 per cent. No significant differences could, however, be detected on the third day. To express the degree of mineralization of the bones, the content of calcium and phosphorus was related to the content of hydroxyproline (collagen) (Figure 3). Reduced calcium/collagen and phosphorus/collagen ratios were found in the bones of the antibiotic treated rats. The

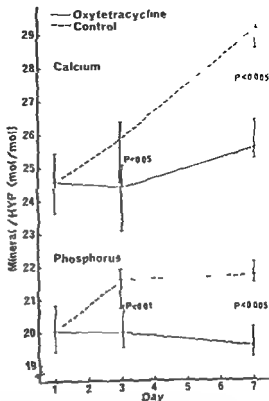


Figure 3 Content of calcium (above) and phosphorus (below) related to the content of hydroxyproline (collagen) in the femurs of the oxytetracycline-treated and the control rats (median with 25 and 75 fractiles)

differences between the two groups were 5 per cent for calcium and 8 per cent for phosphorus on the third day of medication, and on the seventh day 11 per cent for calcium and 10 per cent for phosphorus.

The content of ^{45}Sr in the femurs related to the collagen content, the specific activity of ^{45}Sr , was significantly less for the rats receiving oxytetracycline than for the controls on the seventh, but not on the third day of medication ($P=0.06$) (Table 1). No differences in the specific activity of ^{14}C -hydroxyproline were found (Table 1). The relationship between these specific activity values, the ratio of the specific activity of ^{45}Sr to the specific activity of ^{14}C -hydroxyproline,

Table 1 Specific activity of strontium 85 and ^{14}C -hydroxyproline, and the ratio of specific activity of ^{85}Sr to ^{14}C -hydroxyproline in the femurs of oxytetracycline-treated and control rats. Four to ten animals in each group
Data given as median with 25- and 75 fractiles

Day	Sp act of ^{85}Sr (dpm/nmol hyp)		Sp act of ^{14}C -hyp(dpm/nmol hyp)		Sp act $^{85}\text{Sr}/\text{Sp act } ^{14}\text{C}$ -hyp(dpm/dpm)	
	Oxytetracycline	Control	Oxytetracycline	Control	Oxytetracycline	Control
3rd	13.46 (13.33-14.56)	NS 15.42 (14.66-17.06)	2.46 (2.28-2.64)	NS 2.38 (2.11-2.67)	5.06 (4.96-5.24)	$P<0.01$ 5.84 (5.68-6.15)
7th	13.39 (12.42-14.00)	$P<0.05$ 14.24 (13.58-14.95)	2.04 (1.88-2.12)	NS 2.07 (1.94-2.20)	6.15 (5.99-6.45)	$P<0.01$ 6.86 (6.66-7.17)

NS = Not significant

Table 2 Concentration of calcium, phosphorus and albumin in serum of oxytetracycline treated and control rats. Ten animals in each group
Data given as median with 25- and 75 fractiles

Day	Calcium (mmol/l)		Phosphorus (mmol/l)		Albumin (g/l)	
	Oxytetracycline	Control	Oxytetracycline	Control	Oxytetracycline	Control
3rd	2.75 (2.67-2.85)	NS 2.78 (2.70-2.84)	2.98 (2.87-3.22)	$P<0.01$ 2.56 (2.51-2.67)	38.6 (38.0-40.0)	NS 38.8 (38.7-40.7)
7th	2.81 (2.72-2.89)	$P<0.05$ 2.86 (2.83-2.92)	3.16 (2.82-3.55)	NS 3.03 (2.9-3.16)	42.7 (41.7-44.2)	NS 41.7 (40.4-43.5)

the accretion ratio (Firschein 1969) is shown in Table 1. The accretion ratio is significantly lower in bone of oxytetracycline-treated rats than in controls both on the third and the seventh day of treatment.

The concentrations of calcium, phosphorus and albumin in serum are given in Table 2. Compared with the controls, the antibiotic-treated animals had significantly higher serum levels of phosphorus on the third day (16 per cent) and of calcium on the seventh day of treatment (6 per cent).

DISCUSSION

Some features of this study are that the accretion of rats receiving oxytetracycline had a smaller size and reduced content of calcium, phosphorus and collagen when compared with controls. Furthermore, the antibiotic was found to affect the accretion of strontium-85, but not the accretion of ^{14}C -hydroxyproline.

The concentrations of oxytetracycline in the serum of the experimental animals were comparable with human therapeutic levels (Otten et al 1975). To achieve these concentrations, however, the dose had to be about five times higher than that needed in humans (30 mg/kg/day) (Harris & Gilman 1975).

The demonstrated reduction in body weight of the oxytetracycline-treated animals is in accordance with earlier experience (Engesaeter & Skar 1978). This observation can be explained by the effects on skeletal growth.

Other possibilities have to be considered, such as a general inhibition of protein synthesis as described by Yeh & Shils (1966), although no inhibition of albumin or collagen synthesis by oxytetracycline has been demonstrated in this or in a previous study (Engesaeter et al 1980). An alternative explanation could be that this broad spectrum antibiotic may have caused such a substantial disturbance of the normal symbiosis between the host and the intestinal microorganisms

(Gustafsson 1971) that it would interfere with the growth of the animal.

^{14}C -proline and strontium-85 are convenient isotopes to use in simultaneous studies of collagen and mineral dynamics (Firschein 1969). Although the general reservations about such isotope techniques have to be taken into consideration in the interpretation of the results (Laitinen 1967, Firschein 1969), the content of ^{14}C -hydroxyproline and ^{85}Sr in the bones indicates the rate of collagen synthesis and of mineralization during the 24-hour period.

Judging by the specific activity of ^{14}C -hydroxyproline, collagen synthesis was not inhibited by the antibiotic. The content of collagen in the bones of the oxytetracycline-treated rats compared with the controls was, however, significantly less on the seventh day of medication. These data might be explained by an increased resorption of collagen in the treated rats. This assumption might also be supported by our previous finding that oxytetracycline may interfere with the cross-linking of collagen (Engesaeter et al 1980). Collagen with defective cross-links has been shown to be more susceptible to degradation than normal collagen (Harris & Farrell 1972).

Enhanced resorption of bone cannot, however, explain the observed reduction in the accretion ratio ($^{85}\text{Sr}/^{14}\text{C}$ -hydroxyproline) and the reduced content of strontium-85, calcium and phosphorus in bones of oxytetracycline-treated rats. The only reasonable interpretation of these findings seems to be inhibition of the mineralization process by the antibiotic, either directly or indirectly.

The mechanism by which tetracyclines interfere with the mineralization process is poorly understood. Bevelander et al (1960) concluded that "the inhibition of mineralization following injection of tetracycline is probably due to the reduction in the number of free cations which subsequently results in the formation of a bone deficient in minerals". One mole of oxytetracycline may form complexes with 1-2 moles of calcium depending on the relative concentrations

(Ibsen & Urist 1962) The amount of calcium bound to the antibiotic at an oxytetracycline concentration of 10 µg/ml would, however, represent only about 1 per cent of the total calcium in serum. It seems therefore, difficult to explain in this way the negative effect of tetracycline on the mineralization as has also been stated by Sternberg (1966) and Shapiro et al (1977).

In vitro experiments have indicated that tetracyclines inhibit bone mineralization by preventing the transformation of amorphous calcium phosphate to crystalline apatite (Wadkins et al 1974). Tetracyclines have also been suggested to induce defects of calcification by inhibiting the accumulation of calcium in the mitochondria of cells preparing for mineralization (Shapiro et al 1977). This intramitochondrial accumulation of calcium is postulated by Lehninger (1970) to be an essential first step in the calcification process. Shapiro et al (1977) found in their tetracycline experiments with chickens a profound drop in the intramitochondrial calcium concentrations and, as also observed in the present study, an increase in the serum calcium level.

Tetracyclines could, however, be considered to interfere with the calcification process in an indirect manner. It has been proposed that the formation of intermolecular cross links in collagen may be a prerequisite for appropriate mineralization of bone matrix (Avioli 1973, Rosenquist et al 1977). Our previous finding that oxytetracycline may impair the cross linking of collagen (Shapiro et al 1980) might therefore, indicate that the reduced mineralization is secondary to an induced defect in the collagen framework.

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EFFECTS OF CLOXACILLIN, DOXYCYCLINE, FUSIDIC ACID AND LINCOMYCIN ON MINERALIZATION AND SOLUBILITY OF COLLAGEN IN YOUNG RATS

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Key words albumin, antibiotics, bones, calcification, calcium, collagen, phosphorus, skin, solubility

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In a previous study (Engesaeter & Skar 1979) the effects of the antibiotics doxycycline, fusidic acid and lincomycin were found to cause reduced solubility of collagen and reduced tensile strength of skin in young rats. Such unwanted effects were, however, not detected in a group of rats receiving cloxacillin.

The purpose of the present investigation was to examine the effects of these four antibiotics on the solubility (cross-linking) of collagen and on the mineralization of bones. Two parameters are of particular interest since another antibiotic, oxytetracycline, has been found to impair both collagen solubility and bone mineralization (Engesaeter et al 1980a, b).

MATERIALS AND METHODS

Male Wistar rats, initially weighing 39-44 g, were used. The animals were divided into five

groups of 10 rats. The first group received cloxacillin, the second doxycycline, the third fusidic acid and the fourth lincomycin. The fifth group of animals served as control receiving only isotonic sodium chloride solution. The antibiotics were administered as intraperitoneal injections every 12th hour for 14 days. Fusidic acid, however, was given by a stomach tube, as intraperitoneal injections in a pilot study caused massive abdominal adhesions. The doses of the drugs in mg/kg/day were 2-12 times higher than the recommended human doses. Plasma concentrations of the antibiotics were, however, comparable with the therapeutic levels in humans. Further information about the animals and the medication was reported in a previous paper dealing with the mechanical properties of bone and skin of these rats (Engesaeter & Skar 1979).

At the end of the 14-day medication period the rats were anaesthetized with ether and blood was collected by puncture of the aorta, death followed by exsanguination. Bones and skin were immediately removed and after mechanical testing stored at -20°C until biochemical examination.

Bone analyses were performed on the left femur after the soft tissues, the cartilages and the epiphyses had been removed. The bones were hydrolyzed in 6M HCl at 125°C for 18 hours, and the content of calcium, phosphorus and collagen was measured as described below.

Skin analyses were performed on skin from the back of the animals, i.e. the most cranial of the three intact skin specimens used in the mechanical testing. The fraction of collagen soluble in saline solution was determined by modifications of the methods of Kivirikko et al (1965) and Gudmundson (1971), as described previously (Engesaeter et al 1980b). In short, the skin specimens were defatted and dried in acetone for 7 days, followed by drying in air at 35°C until constant weight was then dried at 18K, Janke in 0.15M NaCl solution before extraction at 4°C in

insoluble" collagen fraction. Both fractions were hydrolyzed in HCl at 125°C for 18 hours before the collagen content was determined.

measuring hydroxyproline, using the method of Firschein (1969). The concentrations of calcium and phosphorus in the bone hydrolysates were assessed using the Abbott Bichromatic Analyzer (Abbott Laboratories, Diagnostic Division, USA). The Bichromatic Analyzer was also applied to measure serum concentrations of calcium, phosphorus and albumin. The kits used in the analyses were those from Abbott Laboratories (A-Gent Calcium and Albumin) and the Phosphorus Auto/Stat kit of Pierce Chemical Comp (Rockford, Illinois, USA).

Serum copper concentration was determined indirectly by measuring ceruloplasmin oxidase activity in serum using the method of Johnson et al (1967).

Table 1 Content of calcium and phosphorus related to the content of hydroxyproline (collagen) in the left femur of the rats receiving cloxacillin, doxycycline, fusidic acid or lincomycin and of the control. Ten animals in each group. * $P < 0.05$ ** $P = 0.01$ (Median with 25 and 75 percentiles).

	Cloxacillin	Doxycycline	Fusidic acid	Lincomycin	Control
Ca/Hyp (mol/mol)	31.08 (29.45–31.78)	30.28 * (29.92–31.17)	30.42 (30.06–31.83)	30.36 (30.08–31.21)	31.2 (30.58–31.8)
P/Hyp (mol/mol)	23.38 (21.71–23.61)	22.19 ** (21.79–23.04)	22.48 (21.87–23.29)	22.56 (22.29–23.40)	22.2 (22.0–22.4)

The median with 25- and 75-percentiles to express the average and the measured values. Statistical significance evaluated by the Wilcoxon test for paired data and differences were considered significant if $P < 0.05$ (Diem & Lentner 1975).

RESULTS

To express the degree of bone resorption the content of calcium was related to the collagen content. Table 1 shows that the rats receiving a significantly lower calcium/collagen ratio (per cent) and phosphorus/collagen ratio (per cent) than the controls. No effects on the calcium/collagen or phosphorus/collagen ratio were seen in the other antibiotic groups.

The skin analyses did not reveal any difference in the solubility of collagen in any of the receiving antibiotics when compared to the controls (Table 2).

Serum analyses however showed that the rats receiving doxycycline had significantly lower concentrations of albumin (3 per cent) than the controls (Table 3). Furthermore the doxycycline treated animals had reduced serum calcium (13 per cent) compared to the controls. No other significant differences in serum concentrations of calcium, phosphorus, albumin or ceruloplasmin were found between the antibiotic treated animals and controls.

DISCUSSION

The present study revealed that the doxycycline treated rats had a significantly lower

	Cloxacillin	Doxycycline	Fusidic acid	Lincomycin	Control
total	3.25	3.85	3.46	3.59	3.64
(%)	(3.01-3.59)	(3.10-4.31)	(3.07-3.88)	(3.21-4.07)	(3.29-4.11)

if calcium and phosphorus compared controls. No effect of the solubility of collagen, however, could be observed after the administration of the antibiotics.

The reduced calcium/collagen and calcium/collagen ratios observed in bones receiving doxycycline indicate impairment of the mineral metabolism. These correspond well with those obtained with another tetracycline antibiotic, tetracycline, which was found to reduce the incorporation of strontium-85 and to reduce the content of calcium and phosphorus (Engesaeter et al 1980a).

These molecules are normally linked together in fibres by specific covalent bonds and cross links. If this cross linking is impaired, the fibres do not attain the normal tensile strength (Uitto & Lichten-

stein 1976) and the collagen becomes more soluble (Lapière & Nusgens 1976). This was proposed as a possible explanation for the reduced mechanical strength and increased collagen solubility found in the oxytetracycline treated rats (Engesaeter et al. 1980b). In the present study no effects on the solubility of collagen were detected in any of the antibiotic treated groups.

Doxycycline treated rats had lower albumin concentrations in serum than the controls. This may indicate impairment of albumin synthesis since doxycycline inhibits the growth of microorganisms by interfering with the protein synthesis (Goodman & Gilman 1975). Several studies (Yeh & Shuls 1966; Morgan & Ribush 1972; Vazquez 1974) have shown that tetracyclines may also affect the animal protein synthesis, although oxytetracycline has not been found to affect the

*Serum concentrations of calcium, phosphorus, albumin and ceruloplasmin of rats receiving doxycycline, fusidic acid or lincomycin and of the control rats. Ten animals in each group. Calcium, phosphorus and albumin analyses five in the ceruloplasmin analyses. * $P < 0.05$ (Median with 25 and 75 percentiles)*

	Cloxacillin	Doxycycline	Fusidic acid	Lincomycin	Control
Ca	2.82 (2.69-2.85)	2.87 (2.81-2.98)	2.75 (2.73-2.79)	2.72 (2.67-2.86)	2.81 (2.78-2.83)
Phos	2.90 (2.77-3.08)	3.19 (2.73-3.40)	3.03 (2.73-3.61)	2.70* (2.38-3.01)	3.10 (2.87-3.40)
Alb	49.4 (48.2-50.6)	47.8* (46.9-50.1)	50.0 (48.4-50.6)	50.6 (49.4-51.4)	50.3 (48.7-51.7)
Ceruloplasmin	0.14 (0.10-0.15)	0.16 (0.14-0.18)	0.14 (0.13-0.15)	0.15 (0.13-0.20)	0.15 (0.14-0.20)

albumin or collagen synthesis (Engesaeter et al 1980b) or the concentration of albumin in serum (Engesaeter et al 1980a) in our previous experiments. If these albumin findings in the doxycycline treated rats indicate a general inhibition in synthesis of proteins including collagen the effect of doxycycline on the cross-linking of collagen might then have been masked since a reduced rate of collagen synthesis also reduces the solubility (Gross 1958, Dawson & Milne 1978).

Serum copper concentration (ceruloplasmin) was measured as copper is a cofactor for the enzyme lysyl oxidase which catalyzes the first step in the cross linking process of collagen (Siegel et al 1970). No reductions in serum copper concentrations were, however, revealed.

The reduced concentration of phosphorus in serum of lincomycin treated animals compared with the controls seems difficult to explain from the presented data.

This study shows that doxycycline may affect mineralization of bone and perhaps protein synthesis. The present biochemical findings, however, provide no definite explanations for the previously observed reductions in dermal strength of rats receiving doxycycline, fusidic acid or lincomycin (Engesaeter & Skar 1979).

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MYCOBACTERIUM KANSASII AND OSTEOARTICULAR LESIONS

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Four patients with an unusual type of bone lesion are reported. The

typical of osteoarticular tuberculosis.

Key words: *Mycobacterium Kansasi*, *Mycobacterium tuberculosis*, osteoarticular lesions

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Chromogens have been isolated from osseous lesions in lungs and lymph nodes (Runyon et al. 1943, Runyon 1959, Goyal & Sen 1962) but these organisms have not been reported to cause osteoarticular lesions. This report presents four patients with osteoarticular lesions from which chromogens were isolated. From another case (not included in the present report) a mixed culture consisting of *Scoto-chromogens* and *Mycobacterium tuberculosis* was isolated. The clinical and radiological picture of the lesions, the histological appearance of the tissue from these lesions, were quite unlike those of typical tubercular lesions. These unusual features necessitated the reporting of these

lesions. The patient was a 30-year-old female who gave a vague history of constitutional symptoms on interrogation. On examination there was an oblong, smooth, tender, cystic and fluctuant swelling, 2.5 cm in diameter, along the lateral border of the left forearm attached to the lower end of the radius. Radiologically (Figure 1) there was a lytic

pyogenic organisms. On Lowenstein Jensen medium chromogens were isolated. No pyogenic organisms were isolated. Histology revealed

REPORTS

Case 1: A 30-year-old female came to the Orthopaedic Outpatient Department of the Institute of Medical Sciences, Banaras Hindu University, Varanasi, in the first week of November 1969, complaining of a painful swelling of the forearm of 3 months' duration on the lateral aspect of the

upper part of the arm. Movements of the shoulder joint were painful and restricted. Radiologically there was a lytic lesion in the upper end of the humerus surrounded by osteoporosis (Figure 2). Based on the clinical and radiological findings, it was diagnosed as a 'tubercular lesion', pyogenic



Figure 1 Case 1 X ray showing a lytic lesion in the lower end of the radius



Figure 2 Case 2 X ray showing a lytic lesion in the head of the humerus

infection and malignancy were kept in mind. Pus aspirated from the fluctuant site was cultured for acid fast and pyogenic organisms. Chromogens were isolated from the culture on Lowenstein Jensen medium. The culture was negative for pyogenic organisms. Histology of the biopsy material gave a picture of a chronic eosinophilic granuloma.

H D S, a 15 year-old male, attended the

Figure 3 Case 3 X ray showing a lytic lesion in the distal part of the femur with osteoporosis

department in February 1970 with fever, pain and swelling in the lower part of the right thigh of 2 months duration. The swelling increased in size for some time and then became stationary. Clinically there was a tender and cystic swelling in the lower part of the right thigh. The cortex of the femur was intact and the knee was free. Radiologically there was a lytic lesion in the lower end of the femur surrounded by marked osteoporosis. The diagnosis of tuberculosis of the lower end of the femur was made, keeping in mind the possibility of pyogenic infection. Pus was cultured for acid fast and pyogenic organisms. Culture for pyogenic organisms was negative but *Mycobacterium* isolated on Lowenstein Jensen medium from the curetted material revealed a chronic inflammatory lesion.

K P G, a 34-year-old male, presented in November 1969 with complaints of a discharging sinus in the upper part of the right thigh of 6 months duration. It started with a small swelling in the upper part of the thigh which ruptured of its own accord and gave rise to a discharging sinus. He had had some intermittent but to no avail. On examination there was a lytic lesion in the proximal femur with a periosteal reaction. The lesion was diagnosed as tuberculous. The pus was cultured and the material submitted to culture for

and for acid fast bacilli Chromogens (tested from Lowenstein Jensen medium No organisms could be isolated

DISCUSSION

In our cases reported here osteoarticular lesions were suspected to be tuberculous in nature (on clinical and radiological grounds) but were found to be caused by chromogens. In our investigation these organisms were found to be photochromogens (*Mycobacterium Kansashi*). These were considered the organisms responsible for the lesions, as no other organism could be isolated.

In all hundred and twenty five osteoarticular lesions were investigated from May 1969 to May 1971 for evidence of tuberculosis. Seven had positive cultures for acid fast bacilli. Four of these cultures were *M. Kansashi* (Lakhanpal et al 1976). These took 4-6 weeks to grow in the culture at 37°C and on further investigation were found to be photochromogenic as well at 37°C on subculture in 2-3 weeks. Radiologically the diaphyseal lesions (cases 1 and 3) could have been mistaken for tuberculous infection. The radiological picture of the lesions caused by these organisms was not typical of osteoarticular tuberculosis. Probably lesions caused by chromogens in bones and joints have a radiological picture which is different from the one caused by *Mycobacterium tuberculosis* or pyogenic

organisms. To establish this however, needs further investigation of a large number of cases.

From three of the lesions the material was submitted for histological examination. The diagnosis in two patients (cases 1 and 3) was non specific chronic inflammation. One case (case 2) was diagnosed as chronic eosinophilic granuloma. Histopathological examination was not done in the remaining case (case 4). It is of interest to note that none of the cases investigated had a clear-cut histological picture of tuberculous lesion. It seems as if the basic pathology of the lesions caused by these organisms is different from the one caused by *Mycobacterium tuberculosis*. This could be the reason for the atypical histological picture in the lesions caused by chromogens.

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ANTERIOR TRANSPOSITION OF THE ULNAR NERVE

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Twenty-four patients with 26 ulnar neuropathies in the elbow region were treated by anterior transposition of the ulnar nerve. The dominant arm was involved in 14 of these patients.

Improvement of paresthesia was found in 17 out of 21 (75 per cent) in this series of patients, 10 out of 18 (55 per cent) had improvement of sensation, 7 out of 14 (50 per cent) had less pain. 10 out of 14 (71 per cent) showed an increase in motor power, but only 2 out of 12 patients (16 per cent) with long-standing muscle atrophy showed any improvement in their condition.

Electromyographic studies (EMG) were carried out before and after operation. The postoperative studies revealed increased motor conduction velocity within the elbow segment of the ulnar nerve in 15 patients. Slowing in ulnar nerve conduction velocity was found in 3 patients, and in 8 the EMG remained unchanged.

Our EMG series indicated that patients with a conduction velocity of less than 40 m/s will certainly benefit more from anterior transposition of the ulnar nerve than will patients whose measurements are within the normal range.

Key words: anterior transposition, electromyography, neuropathy.

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pathies of the ulnar nerve at the elbow result in severe impairment of hand function, secondary to pain, paresthesia, or motor function.

Various etiologies for the pathogenesis of nerve lesions at the elbow have been described. They include primary and delayed nerve palsies which result from various traumatic and non-traumatic factors (Engelberg & Larsen 1973, Gay & Love

PATIENTS

Twenty-four patients in our department underwent surgery for entrapment neuropathy of the ulnar nerve during the period 1971-1976. They included 17 men and 7 women whose ages ranged from 19 to 68 years (average 40 years). The left hand was involved in 12 cases and the right in 10. 11 had bilateral involvement. In 14 cases the dominant hand was involved. Only 4 patients had post fracture ulnar nerve entrapment, in 20 patients idiopathic etiology was diagnosed.

The mean duration of symptoms from the initial appearance to actual surgery was 8 months, ranging from 4 months to 2 years. Patients with long-standing symptoms of over 2 years were not treated by surgery.

The purpose of the present paper is to report the clinical and electromyographic operative results following decompression and anterior transposition of the ulnar nerve in a series of 24 patients.

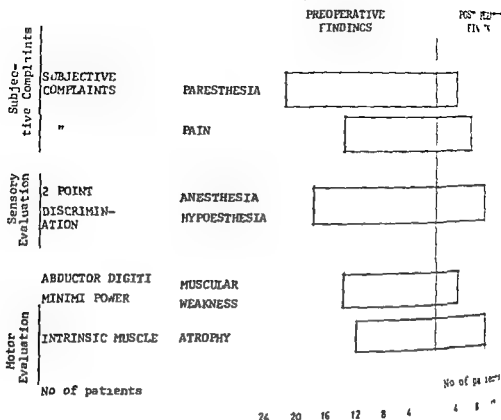


Figure 1 Clinical symptoms and results of clinical examinations

METHODS

Clinical examination included the 2 point discrimination test for sensation. Motor power was evaluated by clinical examination of the abductor digiti minimi and graded from 0-5. Evaluation of intrinsic muscle atrophy was made by inspection. The range of elbow motion was measured with a goniometer. Plain x rays of the elbow consisting of postero-anterior lateral and two oblique views as well as electromyographic examination of the ulnar nerve were performed.

These examinations were repeated 6 months after surgery. Anterior transposition of the ulnar nerve without epicondylectomy was performed on all the patients in this series. Two of them had to undergo further surgery due to recurrence of symptoms. A neurolysis was performed in one and an epicondylectomy was carried out in the other patient.

RESULTS

The professional distribution of our patients failed to demonstrate predisposing factors, as

there were 13 non manual workers and 8 manual workers.

Figure 1 summarizes the symptoms before and after surgery. 17 out of 21 cases (75 per cent) paresthesia improved. 10 out of 14 (50 per cent) gained improvement in sensation. 14 (71 per cent) showed an increase in power but only 2 out of 12 patients (17 per cent) with long standing muscle atrophy showed improvement in their condition.

For further evaluation the patients were divided into two groups. Group A with duration of symptoms of over 1 year prior to surgery and Group B with duration of symptoms less than 1 year prior to surgery. 14 patients in Group A, and 6 out of 8 in Group B. Motor symptoms improved in 9 out of 14 patients in Group A whereas in Group B 4 out of 8 patients benefited from surgery (Figure 2).

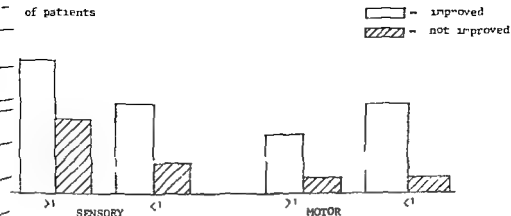


Figure 2 Improvement of sensory and motor function in relation to duration of symptoms

teen patients gained relief after having the operation. Two reported aggravation of symptoms, and in 6 there was no change. Following surgery, electromyographic improvement of motor conduction velocity at the elbow was found in 15 patients. A decrease in conduction was observed in 3, and EMG remained unchanged in 8 patients. In 10 patients conduction velocity improved from 0 to 20 m/s after operation (Figure 3).

DISCUSSION

Paralysis of the ulnar nerve did not occur more frequently in manual workers than in the white collar professions in this study, nor did it have any correlation with handedness. Wilson & Apfelberg (1972) reported relief after anterior transposition of the ulnar nerve in 10 out of 10 patients. They described that the preoperative symptomatology was frequently severe. However, muscle atrophy cannot be completely reversed unless treated at a very early stage. This is also confirmed in our study where marked sensory improvement was gained in 75 per cent of patients with numbness and in 55 per cent of those with sensory loss, but in only 16 per cent with muscle atrophy. Agnægård & Nilner (1977) concluded that the operation appears to produce the best

results. Wilson (1973) found that the degree of surgical success as regards symptom alleviation is inversely proportional to the duration of preoperative symptoms. This was not confirmed in the present study; the difference between the two groups was not significant, as long as one remains within the 2-year boundary.

It would appear that symptomatic improvement does not have any correlation with

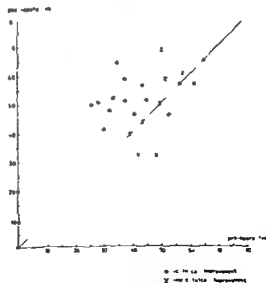


Figure 3 Results of EMG examination in 24 patients (26 hands) before and after surgery

age Of the 5 patients who failed to obtain any relief, 3 were below 40 years of age

Most reports on anterior ulnar nerve transposition have been encouraging McGowan (1950) reported a 75 per cent success rate Gay & Love (1947) achieved 80 per cent satisfactory results Sunderland (1968) found that out of 14 patients only 6 improved, while 4 were considered to be worse after surgery Lugnegård (1977) found that 11 out of 18 (61 per cent) had achieved enhancement of motor and sensory power, but only 6 had recovered completely

Our series seems to be in keeping with previous reports indicating marked improvement in motor and sensory function after surgery

Various reports mentioned in Lugnegård's study (Lugnegård 1977) note electromyographic improvement of motor nerve conduction velocity, even in cases where clinical improvement was not found

As set forth in Figure 3, all patients who had an EMG motor conduction velocity under 40 m/s prior to operation showed significant improvement following surgery This correlated well with their clinical improvement

In patients with EMG findings of 40 to 70 m/s, we found both an amelioration in motor conduction velocity and in clinical symptoms respectively

CONCLUSION

There is a great possibility whose EMG is within normal limits to improve clinically However the improvement is less striking than in patients with ulnar neuropathy and an EMG of less than 40 m/s These cases will certainly benefit from anterior transposition of

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POSTERIOR DISLOCATION AND FRACTURE-DISLOCATION OF THE SHOULDER

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Two cases of posterior dislocation (PD) and four cases of posterior fracture-dislocation (PFD) of the shoulder are reported. There was one bilateral PD and two bilateral PFD. One PD was treated with closed reduction but in three cases of PFD operative reduction was necessary. All measures were applied in the late phase within 1 to 10 months after the injury with good primary results. However, because of posttraumatic arthrosis, the final result was poor. The average follow-up period was 4 years. The diagnosis of posterior dislocation is often missed. An axillary X-ray is essential.

Key words: posterior fracture-dislocation, posterior dislocation, shoulder dislocation.

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Posterior dislocation (PD) of the shoulder is a common injury in comparison with anterior dislocation. The first accurate description of the clinical appearance of unilateral PD of the shoulder has been ascribed to Cooper (1839). Between 1.5 and 4.3 per cent of all shoulder dislocations are posterior dislocations (Warrich 1948, McLaughlin 1952, Taylor & Wright 1952, Rowe 1956, Neer 1962). The dislocation is often associated with minor fractures, such as a fracture of a small fragment from the inferior aspect of the head.

Fractures associated with posterior dislocations of the shoulder, posterior fracture-dislocations (PFD), are rare. Neer et al. (1962) reported 14 PFD in a material of 1500 dislocations of the shoulder (0.9 per cent) (Neer 1953, O'Connor & Jacknow 1956, Bell 1957, Chattopadhyaya 1970). Approximately 10 per cent of all PD (Arden 1956, Shephard 1960, Neer 1969) and 14 bilateral PFD have been reported (Mynter 1902, Mills 1974).

Trauma mechanism

Mechanical trauma may be the cause in unilateral cases, but convulsive seizures, such as those occurring in a fit or in electric shock, are the single most common cause of bilateral PD and PFD. When posterior dislocation is bilateral, it has nearly always been caused by a convulsive seizure (Kelly 1954, Shaw 1971, O'Flanagan 1975).

The typical position of the shoulder during a convulsion is adduction, internal rotation and flexion. A massive contraction of the shoulder girdle muscles forces the humeral head against the acromion and the glenoid fossa, providing the force necessary to produce dislocation. If the convulsion contraction continues, a typical PFD is produced. Increased stress on the notched anatomical neck, which impinges against the glenoid rim, applies a shearing force to the humeral head, and the subscapularis and infraspinatus complexes are torn off from their respective fragments (Neer 1970).

age. Of the 5 patients who failed to obtain any relief, 3 were below 40 years of age.

Most reports on anterior ulnar nerve transposition have been encouraging. McGowan (1950) reported a 75 per cent success rate. Gay & Love (1947) achieved 80 per cent satisfactory results. Sunderland (1968) found that out of 14 patients only 6 improved, while 4 were considered to be worse after surgery. Lügnergård (1977) found that 11 out of 18 (61 per cent) had achieved enhancement of motor and sensory power, but only 5 had recovered completely.

Our series seems to be in keeping with previous reports indicating marked improvement in motor and sensory function after surgery.

Various reports mentioned in Lügnergård's study (Lügnergård 1977) note electromyographic improvement of motor nerve conduction velocity, even in cases where clinical improvement was not found.

As set forth in Figure 3, all patients who had an EMG motor conduction velocity under 40 m/s prior to operation, showed significant improvement following surgery. This correlated well with their clinical improvement.

In patients with EMG findings of 40 to 70 m/s, we found both an amelioration in motor conduction velocity and in clinical symptoms respectively.

CONCLUSION

There is a great possibility for those whose EMG is within normal limits to improve clinically. However, clinical improvement is less striking than in peripheral ulnar neuropathy and an EMG of 140 m/s. These cases will detach from anterior transposition.

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Diagnosis

Posterior dislocation of the shoulder is frequently overlooked at the first examination and the treatment thus becomes more difficult. In a typical case of acute PD, the arm is locked in internal rotation and adduction. Palpation of the humeral head in a posterior position provides the only conclusive clinical evidence of PD. But palpation may be misleading since the spastic deltoid, a haematoma, and oedema may obscure the condition. When there is a concomitant fracture the arm may be in any position and motion at the fracture site may be misinterpreted as joint motion.

In PD there is often little or no deviation from the normal picture in A-P X-ray views. Since the arm usually will be immobilized in internal rotation at the time of X-ray examination, the tell-tale overlapping of the humeral head and the glenoid fossa may mimic the normal overlapping seen with the shoulder in full internal rotation. An axillary X-ray must be obtained to confirm the diagnosis. If care is taken in positioning the arm, the 30 degrees of abduction necessary to obtain this view will not do any further damage or cause undue discomfort.

Treatment

A variety of treatments has been reported (closed reduction and plaster (Kelly 1961), closed reduction and wire fixation (Wilson & open reduction and internal fixation (Prillaman & Thompson 1969 for excision of fragments (Wills 1974), cement arthroplasty (Aufranc et al. 1971) and arthrodesis (Nordeck 1977)).

Within a few days of the closed reduction with the arm in internal rotation, abduction and external rotation is inadequate (Greenhill 1972). In neglected cases, contractures develop in the shoulder joint. The compression fracture of the humeral head deepens necessitating operative reduction.

The specific pathological lesion in the patient should determine the choice of procedure: a posterior Putti-Platt or type procedure, fixing the subscapular tendon within the compression fracture of the scapula (McLaughlin 1952) or osteotomy of the scapula (Scott 1967). A posterolateral Hybbinette operation may be indicated to prevent redislocation if there is a humeral defect, or the capsular strain.



Figure 1 Case 1 Radiographs of the shoulder joints A and B, C and D Shoulder joints at the accident E Right shoulder joint 2 months after operative reduction F and G Right shoulder joint 3 years after reduction



inadequate (v Hellens 1946) In a posterior Putti-Platt repair internal rotation will be limited permanently to about 45 degrees (Severin 1952)

CASE REPORTS

Case 1 A 41-year-old woman received an electric shock through her right hand Bilateral PFD of the humerus was diagnosed 4 weeks after the accident Closed reduction was unsuccessful After 3 months the patient's shoulders appeared almost normal, but their mobility was greatly reduced there was 45 degrees lateral abduction and 90 degrees forward flexion but external rotation was absent (Figure 1) The PFD of the right shoulder was surgically reduced, the pseudoarthrosis revised and the caput affixed to the distal fragment with a spongiosa screw The left shoulder was not operated on as there was mobility and the pain was not significant Three years after the operation the right shoulder was relatively free of pain, but the left shoulder was painful The patient was able to anteriorly flex and abduct her arms about 100 degrees. External rotation was absent. X-ray showed caput necrosis and arthrosis in the right glenohumeral joint

Case 2 A 48-year-old epileptic woman sustained a bilateral PFD of the shoulder in conjunction with an epileptic attack The condition was diagnosed 3 weeks later and operative reduction of the right shoulder was performed 4 months later A redislocation occurred and a posterior Eden-Hybbinette procedure was carried out A severe arthrosis developed (Figure 2) The left shoulder was left untreated Three years later the patient had 90 degrees of anterior flexion in the arms Abduction was 30 degrees on the operated side, and 70 degrees on the contralateral side External rotation was absent X-rays revealed severe arthrosis in the right glenohumeral joint

Case 3 A 69-year-old woman suffered an attack of unconsciousness Bilateral PFD of the shoulder joints was diagnosed 3 months later Closed reduction of the right shoulder was performed 10 months after the accident and retention was ensured by the use of two Kirschner pins and an abduction splint The left side was not treated Two years after the reduction the patient was able to abduct both arms 90 degrees and flex them

anteriorly 140 degrees. External rotation was absent X-rays revealed severe right glenohumeral joint.

Case 4 A 32 year-old man sustained a fracture of the anatomical collum of the left humerus with an epileptic attack. The patient had been treated primarily with a screw. Mobility of the shoulder remained good and 2 years later the aftermath of the diagnosed External rotation Operative treatment was not of the long standing dislocation. compression groove in the caput was flattened

Case 5 The coat of a 38-year-old man between the rollers of a printing press patient's shoulder backwards and the right shoulder The joint was following day The function remained months later the torn joint capsule was and the acromion was resected motion at the shoulder joint was shoulder became almost painless there was 60 degrees active abduction, forward flexion and 10 degrees X rays showed severe posttraumatic arthrosis

Case 6 A 14-year-old school boy fell from a bicycle and sustained a PFD of the left shoulder Closed reduction was not successful and later operative reduction and fixation of the caput to the scapula with 3 pins was performed The dislocation recurred Atrophy of the shoulder result of nerve damage in conjunction with primary injury was demonstrated. The shoulder remained poor After 2 years he refused to undergo operative reduction condition was unchanged 7 years after X-rays showed severe caput necrosis

DISCUSSION AND CONCLUSIONS

Posterior dislocation of the shoulder is a rather rare diagnosis seems often to be delayed X-ray examination is essential in cases. Early reduction is exceedingly important The primary result of delayed reduction is usually good, but the long-term

* - 1 B Antero-posterior and anteroposterior views of the shoulder joint one week after the reduction



in the development of painful posttraumatic arthrosis, are discouraging. It seems obvious that the vessels of the humeral head are so badly damaged during or after the dislocation that necrosis is inevitable. On the basis of our material we are unable to determine whether the avascular necrosis could have been avoided with adequate primary treatment.

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BI-POSTERIOR DISLOCATION OF THE SHOULDER COMBINED WITH FRACTURE OF THE PROXIMAL HUMERUS

Report

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A 28-year-old turner presented with bilateral posterior fracture-dislocation of the shoulders following an epileptic seizure. He was treated by open reduction of the humeral heads and fixation of the oblique fractures with screws.

At the follow-up examination 2 years postoperatively shoulder mobility was satisfactory, and the patient could return to his previous work.

Key words: fracture, humero-scapular joint, posterior dislocation

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Posterior dislocation of the shoulder with fracture of the proximal humerus is uncommon (Wilson & McKeever 1969, Shaw 1974, Vastamaki & Solonen 1974, Aufranc 1975). In almost all cases an epileptic seizure is the aetiological factor (Aufranc 1975, Shaw 1971, O'Flanagan 1975). In the case of the convulsions the humerus is rotated inwards and bent, when the pull of the scapular region pull on the muscles, infraspinatus, teres minor, latissimus dorsi and teres major cause to dislocate the head in a medial direction. The humeral neck may fracture, and an oblique splintered fracture can follow the contraction of the muscles infraspinatus and teres major (Cooper 1839, Keith 1904, McLaughlin 1952, 1971).

We present here a case in which bilateral posterior fracture-dislocations were treated by

CASE REPORT

A 28-year-old turner with daily consumption of alcohol for a period of several years was admitted to the hospital following bilateral posterior fracture-dislocation of the humeri. Sixteen days earlier (1976-10-21) the patient had had a violent epileptic convulsion of the grand mal type after abstaining from alcohol for 4 days.

The fracture-dislocations were diagnosed (Figure 1) on the 14th day after the accident at a

drugs

Abundant haemorrhages were present in both upper extremities. The humero-scapular joints were totally fixed, and the humeral heads could be palpated behind the glenoid. The patient experienced severe pain when trying to move the joints. Posterior dislocations as well as proximal oblique fractures of the humeri were seen on radiological examination.

On the 20th day after the injury the patient was operated on through an antero-lateral approach between the deltoid and pectoral muscles. The



Figure 1 Posterior dislocations and oblique fractures of the proximal humerus after reposition and operative fixation with screws

joint was opened after division of the insertions of m pectoralis major and m subscapularis. The fracture was located medial to tuberculum minor and the caput fragment was found to be displaced into the posterior compartment of the joint hooked on to the edge of the glenoid. The caput was reduced as were the fracture fragments. The fracture was then fixed with AO-compression screws. When the operative wound was closed the humeral head was additionally fixed with Kirschner wires to the acromion as described by Wilson & McKeever (1949) the same procedure

being performed on both sides. The humeral head was fixed to the body by elastic bandage. Kirschner wires were removed 10 weeks postoperatively. The wounds healed without infection. Mobilization of the shoulder was started 10 weeks postoperatively. After 10 weeks there was a good range of motion which had been maintained at the 10-week follow-up examination (1979-01-11). The range of motion was 170° rotation inwards 90° and outwards 170° both shoulders, whereas abduction was 110° on the left side compared with 110° on the right.



Fig. 1. Range of flexion of the right humero-glenoid joint at follow-up 2 years after the operation.

(b) Radiographs showed that the fractures were reduced, and the humeral heads were seated concentrically in the glenoid fossae (Fig. 1). The patient was able to return to his occupation.

DISCUSSION

Cases of bilateral posterior fracture-dislocation of the shoulders reported in the literature were usually not recognized until a long time after the injury and had to be surgically treated. There was no postoperative re-dislocation, and when capsuloplasty was not performed, a reversed Putti-Platt or an Eden-Harris procedure has been recommended by some surgeons with the additional aim of preventing a re-dislocation (Greenhill 1972). In

our case, as in that of Wilson & McKeever (1949), sufficient stabilization was achieved by simply transfixing the humeral head to the acromion using Kirschner wires. Shaw (1971) reports an unsatisfactory postoperative result with limitation of movement following replacement with endoprosthesis 3 and 4 weeks after the injury, while Vastamäki & Solonen (1979) report successful treatment by open reduction and internal fixation with a screw as late as 3 months after the injury.

We are of opinion that the latter case, and our own, contradict the opinions of Wilson & McKeever who consider that unrecognized fracture-dislocations treated weeks after the injury are likely to give poor results with marked loss of motion and a painful shoulder. In cases of this type we advocate open reduction and internal fixation as described in this report.

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GENITAL PSEUDARTHROSIS OF THE CLAVICLE

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Congenital pseudarthrosis of the clavicle is a rare entity. Its aetiology and pathogenesis still remain obscure. The condition is predominantly right-sided. Differential diagnosis lies between birth fracture and cleido-cranial dysostosis. Surgery when indicated gives good results.

Key words: clavicle, congenital, pseudarthrosis

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Genital pseudarthrosis of the clavicle is first described by Fitzwilliams and St Pierre in 1910 and 1930, respectively, each described one case. Since 1930, 15 authors have described cases in the English medical literature. In 1930, Behringer & Wilson introduced strict criteria to be fulfilled in order for a case to be described as "fully documented": the lesion must be present within the first 2 years, no history of trauma and an X-ray showing discontinuity of the clavicle. Only 18 cases fulfil these requirements. The lesion is predominantly right-sided. Three cases of left-sided congenital pseudarthrosis have been described (Ghormley et al 1941, Wall 1970, Gibson & Carroll 1970). One of these (Gibson & Carroll 1970) had dextrocardia (Gibson & Carroll

1970). In the few cases of bilateral congenital pseudarthrosis have been described (Ignol 1948, Stevenson 1968, Herman 1970, Gibson & Carroll 1970). Only in seven cases has the lesion appeared on the side lateral to the heart.

In this condition there is a defect just lateral to the middle of the clavicle and there is a space between the bone fragments. At birth or later a prominence may be felt at the junction of the middle and outer thirds of the clavicle. This is due to the medial end of the

lateral fragment being pulled upwards and backwards while the lateral end of the medial fragment is pulled upwards and forwards. Thickening of the bone ends adds to the deformity. The medial fragment is the larger of the two. The condition gives an asymmetrical appearance to the trunk when viewed from the front. When viewed from behind the medial border of the scapula is more prominent than that on the normal side. The shoulder of the involved side is lower, further forward and nearer the midline than the opposite one. The shoulder point can be forcibly adducted towards the midline through a considerable range.

Apart from occasional aching, symptoms are relatively few. In many cases the prominence increases with age and may cause difficulty with dress or a disfiguring appearance especially in females.

There is usually a palpable discontinuity between the clavicular fragments and mobility is easily elicited. A search for café-au-lait spots and other skeletal abnormalities is essential in establishing a diagnosis.

Radiological appearances are characteristic — a lack of bone continuity in the middle third of the clavicle without evidence of reactive bone. Absence of callus distinguishes the condition.



Figure 1 Congenital pseudarthrosis of the right clavicle — a four and a half year old male



Figure 2 Congenital pseudarthrosis of left clavicle and bilateral cervical ribs, the left being larger



Figure 3 Congenital pseudarthrosis of right clavicle in a one year and ten months old male

CASE REPORTS

In the period 1956 to 1978 four cases of congenital pseudarthrosis of the clavicle have been seen in this hospital

Case 1

A four and a half year old boy presented in 1963 with a lump over the middle third of his right clavicle. This was pain free and had been noticed during the first year of life. The deformity was increasing. The level of the right shoulder was lower than the left. X-ray showed a pseudarthrosis (Figure 1). This boy was treated surgically. A tibial bone graft was laid across the defective area and was wired to both clavicular fragments. Solid union followed.

Case 2

A one and a half year old girl presented in 1968 with a mass over the centre of her left clavicle.

There was no history of trauma.

and sound bony union occurred. This bilateral cervical ribs the left being larger.

Case 3

A 6-year-old girl attended in 1973 increasing deformity over the middle right clavicle. This was first noticed two years. There was no history of injury. Movement was painless and normal. X-ray showed a pseudarthrosis. Surgery was performed. The area of pseudarthrosis being excised. Bone ends were roughened and iliac bone chips were laid around the union. Solid union occurred.

Case 4

A 22-month-old boy presented in 1967 with a pain free lump over the centre of his left clavicle. There was no history of trauma. X-ray was seen on X-ray (Figure 3). Movements were not limited. This child was reviewed periodically. Unless indicated will not be carried out.

DISCUSSION

This rare condition has to be distinguished from post-traumatic pseudarthrosis, cleidocranial dysostosis. In the condition there is often a history of labour or of trauma. A period of immobility of the upper limb usually follows. There is excessive callus formation. This is a common feature in post-traumatic pseudarthrosis (Wall 1970).

The operative findings are characteristic when the lesion is congenital. There is articular cartilage on the bone ends. Sometimes synovial lining is evident in the area of the defect.

In cleidocranial dysostosis the defect is very often bilateral and is associated with other stigmata such as wide fontanelles, wide suture lines. The skull is large. The bones are small and the teeth are delayed. Deficiencies of the pelvic ring and

ses in the hands and feet are common
disorder is familial

aetiology of congenital pseudarthrosis
clavicle is obscure. Deficiency in ossi-
on is suggested. Mall (1960), Fawcett
and Parker state that the clavicle
arises from two centres and these centres
by the 45th day of intrauterine life
of fusion will result in congenital
arthrosis. Koch (1960), in reviewing the
aetiology of the clavicle, suggests that
only one ossification centre. Gibson &
Carroll (1970) support this view. Although ossi-
fication from two centres may occur in con-
genital pseudarthrosis, Koch (1960) and
Gibson & Carroll (1970) feel this is abnormal
and would require an explanation.

Roberts et al (1975) suggest that, as
majority of cases occur on the side
opposite to the heart, the close relationship of
the subclavian artery to the developing
clavicle may play a part. Cervical rib or
elevated upper ribs will bring the
vessels very close to the clavicle.
Exaggerated arterial pulsation may
with ossification and may result in a
pseudarthrosis. They showed some examples
in their series. Case 2 in our series had
cervical ribs, the left being larger
(Fig. 2).

The lesion seen in association with
cranio-cleido dysostosis may be a true
pseudarthrosis produced by the abnormally
elevated ribs bringing the subclavian vessels
close to the clavicle.
Four cases fit into the previously well-
known patterns and two of them satisfy
the criteria for "full documentation". The
two who have had surgery achieved
excellent results and at 15, 11 and 10 years of
age are symptom-free.

Various procedures have been carried out for
surgical treatment of this condition.
Gibson & Carroll (1970) emphasizes that internal fixation
should not be used while Sakellariades (1961)
has a 75 per cent failure rate when internal
fixation was not used. Our methods have
been successful but we have had union in all three

CONCLUSIONS

1 Congenital pseudarthrosis of the clavicle is
a rare lesion occurring almost exclusively on
the side opposite the heart.

2 Its aetiology is obscure. Primary defects
in ossification or defects in ossification
secondary to subclavian pulsation may be
causative factors.

3 Surgery is indicated only if there is in-
creasing pain or deformity.

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Figure 1 Congenital pseudarthrosis of the right clavicle - a four and a half year old male



Figure 2 Congenital pseudarthrosis of left clavicle and bilateral cervical ribs the left being larger



Figure 3 Congenital pseudarthrosis of right clavicle in a one year and ten months old male

CASE REPORTS

In the period 1956 to 1978 four cases of congenital pseudarthrosis of the clavicle have been seen in this hospital.

Case 1

A four and a half year old boy presented in 1963 with a lump over the middle third of his right clavicle. This was pain free and had been noticed during the first year of life. The deformity was increasing. The level of the right shoulder was lower than the left. X-ray showed a pseudarthrosis (Figure 1). This boy was treated surgically. A tibial bone graft was laid across the defective area and was wired to both clavicular fragments. Solid union followed.

Case 2

A one and a half year old girl presented in 1968 with a mass over the centre of her left clavicle.

There was no history of trauma. Prior to surgery was shown on X-ray (Figure 2) to be increasing. Surgery was carried out at the age of four. A tibial bone graft was laid across the defect and sound bony union occurred. This child has bilateral cervical ribs the left being larger.

Case 3

A 6-year-old girl attended in 1974 with increasing deformity over the middle third of the right clavicle. This was first noticed at the age of two. There was no history of trauma. The movement was painless and normal. X-ray showed a pseudarthrosis. Surgery was carried out in the area of pseudarthrosis being most marked. The bone ends were roughened and three iliac bone chips were laid around the defect. A sound union occurred.

Case 4

A 22 month-old boy presented in 1977 with a pain-free lump over the centre of his right clavicle. There was no history of trauma. The lump was seen on X-ray (Figure 3). The movements were not limited. This child is reviewed periodically. Unless indicated otherwise surgery will not be carried out.

DISCUSSION

This rare condition has to be distinguished from post-traumatic pseudarthrosis of the clavicle in cleido-cranial dysostosis. In the latter condition there is often a history of difficult labour or of trauma. A period of limited movement of the upper limb usually follows. There is excessive callus formation. Pseudarthrosis is a common feature in post-traumatic pseudarthrosis (Wall 1970).

The operative findings are characteristic when the lesion is congenital. The articular cartilage on the bone ends is sometimes synovial lining is evident in the area of the defect.

In cleido-cranial dysostosis the clavicular defect is very often bilateral and other stigmata such as wide fontanelles, wide suture lines. The skull is large and the bones are small and the teeth are small. Deficiencies of the pelvic ring and the

CAUDA EQUINA SYNDROME IN LUMBAR DISC DISEASE

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A series of 42 patients with lumbar disc disease and herniation presenting with the cauda equina syndrome, has been studied. It was observed that pure disc herniation accounted for the syndrome in five cases only. Associated structural lesions were contributory factors in the remaining 37 cases, and operative manipulation and trauma during disc removal through an interlaminar approach was the added factor in two of them. Wide laminectomy with excision of the overhanging facet joints and adequate visualization of the lumbar nerve roots has been found to be the ideal procedure for disc removal and for relief of the symptoms, including backache. No postoperative spinal instability has been observed. There was no mortality and the morbidity was insignificant. All cases have been followed up and 'good to excellent' results were obtained in 95 per cent of patients, and 'fair' results in the other 5 per cent.

Key words: cauda equina syndrome, herniation, limited approach for disc removal, lumbar disc disease, structural changes in the spine.

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The term "cauda equina syndrome" is usually used to indicate a group of symptoms and signs caused by a compression radiculopathy of one or more nerve roots in the lumbar region.

The clinical manifestations include severe pain in one or both lower limbs, motor weakness, sensory or reflex abnormalities, or sphincter disturbance. Although there are various causes of this syndrome, this communication is concerned with those associated with lumbar disc disease. There were no cases of the rare, complete cauda equina paralysis from massive extrusion which has been reported previously (O'Connell 1950, Robinson 1965, Gifford 1972).

It is generally accepted that a disc herniation commonly causes compression of a single nerve root and this is easily explained both on anatomical and clinical grounds. Since the anterior longitudinal ligament reinforces the

annulus in the midline, most disc herniations occur in the lateral part of the floor of the spinal canal, where the disc material compresses the adjacent lower root as it courses in the lateral recess on its way to the exit foramen. In recent years, however, disc lesions causing atypical or multiple root involvement, simulating an expanding lesion, have been demonstrated both myelographically and operatively (Schlesinger & Taveras 1953). The terms "midline" or "large lateral" disc are commonly used to describe such cases.

We describe in this communication a group of 42 patients who presented with low back pain associated with multi-radicular neuropathy in one or both lower limbs. Plain radiographs of the lumbar spine showed various changes, including narrowing of disc spaces, minor degrees of listhesis and evidence of spondylosis. Myelography was

carried out in all cases and showed various degrees of obstruction to the flow of oil varying from minor to severe. In all cases surgical exploration by means of full laminectomy was carried out. In most of the cases, a significant associated structural lesion of the spine was found to be responsible for the syndrome. The purpose of this paper is to emphasize these associated spinal abnormalities in cases of disc herniation, their role in the causation of the cauda equina syndrome and the rationale of disc removal through a wide laminectomy.

PATIENTS AND METHODS

Between 1974 and 1976, 42 patients with lumbar disc disease and herniation, presenting with the cauda equina syndrome, have been admitted and

treated under the care of one of the authors. Twelve of them had already undergone surgery elsewhere. In this surgical group, no operation had achieved permanent relief (6 weeks to 6 months) in six to nine cases, four, and had been followed by a significant neurological deficit in two. The whole group, including the 12 surgical cases, is considered together.

There were 27 males and 15 females. The ages ranged from 26 to 69 years. The duration of symptoms before admission was 1 to 12 months.

History varied between 2 years and 2 months. Symptomatology is analysed and set out in Table 2.

Surgical exploration was invariably carried out by means of a full laminectomy and emphasized that the extent of the operation was decided by clinical and radiological findings. Plain radiographs had little influence. Significant lesions recognized and treated are set out in Table 2.

Table 1 Analysis of preoperative features and comparison with the results of operation in 42 cases of cauda equina syndrome in the lumbar discs

Preoperative features (no. of cases)		Results of operation (no. of cases)
Lumbar backache	40	Occasional mild backache
Lower limb pain	42	Occasional mild pain in lower limbs
Paraesthesia	34	Recovered
Weakness in lower limbs	24*	Residual weakness
Vesical disturbances	14	Recovered
Reduced mobility of lumbar spine	36	Disappeared
Diminished lumbar lordosis	24	Disappeared
Lumbar scoliosis	4	Disappeared
Local tenderness	26	Disappeared
Positive SLRT	36	Disappeared
Positive F\ST	7	Disappeared
Positive SLRT and F\ST	4	Disappeared
Wasting of muscles	6	Residual wasting
Weakness of muscle group	14)	Recovered
Foot drop	8	Recovered
	24*	
Severe paraparesis	2)	Residual weakness
Hypoalgesia and hypoaesthesia	20	Recovered
Anaesthesia	11	Recovered
Hyperaesthesia	4	Recovered
Absent ankle jerks	14	Persisted
Reduced ankle jerks	4	Persisted
Reduced knee jerks	3	Recovered

2 Causes of cauda equina syndrome in lumbar discs (42 cases)

Case	No of cases
Disc herniation	
Herniation alone	3
+ double spondylolisthesis	1
+ 1° spondylotic stenosis	
+ spondylolisthesis	1
+ disc herniation	
+ herniation alone	1
+ 2° spondylotic stenosis	28
+ 1° spondylotic stenosis	4
+ 1° spondylotic stenosis	
+ trauma	2
+ lateral disc herniation	
+ herniation alone	1
+ 2° spondylotic stenosis	
+ spondylolisthesis	1
	42

Follow-up has so far been maintained for from 1 to 10 years. The results are described in Table 3

RESULTS

Table 1 summarizes the analysis of the pre-operative features in this series and a comparison is made with the results of operation. Pain in the lower limbs was the most important clinical feature and was present in all cases. It was ipsilateral in 21, bilateral in 19 and contralateral in only three cases. Postoperatively it disappeared completely in 34 cases. Four patients experienced occasional mild pain in the lower limbs. Chronic backache persisted in only six of the cases, being mild and intermittent and allowing normal activity. Paraesthesiae were present in 34 cases, bilateral in 12, and unilateral in 22. Sensory deficit was complete in all cases. Evidence of muscle wasting was noted in six cases. Weakness in one or both legs was present in 24, amounting to a marked deficit in two. Muscle wasting persisted in 10 and muscle weakness persisted in 10 patients. Spinal, tension and sensory signs, including saddle anaesthesia in three, were

variable but all cleared up postoperatively. The vesical disturbances, including retention of urine in four, similarly recovered completely. The absence of ankle jerk was noted unilaterally in eight, bilaterally in six and depressed unilaterally in four cases. The knee jerk was depressed in three cases, including one bilaterally. The ankle jerk remained absent bilaterally in two, unilaterally in two and depressed in one.

It is observed that the disc herniation alone caused the cauda equina syndrome in five cases only (Table 2). Structural changes in the spine associated with the disc lesion are collectively called spondylosis and this was responsible for the syndrome in the remaining 37 cases. The terms "primary" (1°) and "secondary" (2°) spondylosis are used here to clarify the causation of the syndrome. In both types the structural changes are similar but they differ in degree and extent. Primary spondylosis occurs in multi-segmental disc disease and causes diffuse narrowing of the spinal canal. Here a disc herniation in an already (asymptomatic) stenotic canal causes a cauda equina syndrome from multiple root involvement. In contradistinction to diffuse spinal stenosis in primary spondylosis, secondary spondylosis represents a segmental narrowing of the spinal canal and generally occurs in an isolated disc lesion. Here the

Table 3 Results of operation for cauda equina syndrome in lumbar disc disease (42 cases)

Results	No of cases
<i>Excellent</i>	
Asymptomatic	
Unrestricted activity	30
<i>Good</i>	
Occasional symptoms,	
Normal activity	10
<i>Fair</i>	
Improved functional capacity	
but with reduced activity	2
<i>Poor</i>	
No improvement	0
Total	42



Figure 1 Myelogram, lateral view, showing a rounded filling defect at the level of L4-5 disc interspace in addition to double spondylolisthesis

structural changes are both prominent and localized and are the cause of the cauda equina syndrome. Segmental spinal stenosis due to secondary spondylosis was the most common cause and was found in 29 cases, including one with spondylolisthesis. The other causes were diffuse spinal stenosis due to primary spondylosis (five, including one

with spondylolisthesis), transverse contents in a primary spondylolisthesis (two) and double spondylolisthesis (one). No recurrence of disc herniation was found at reoperation in patients submitted to surgery. Segmental spinal stenosis was responsible for symptoms and operative trauma through a posterolaminar approach for disc removal in primary spondylolisthesis, stenotic canal, etc.

The two patients with 1st degree spondylolisthesis and a third with 2nd degree true and pseudospondylolisthesis were X-rayed repeatedly at increasing intervals of time for up to 1 year from operation to determine whether or not spondylolisthesis had occurred. In no case did this occur, including the case with double spondylolisthesis (Figures 1 and 2). All patients maintained an excellent clinical result 1 year later.

Results of operation were assessed on a clinical basis by considering the patient's ability and the capacity to work. "Good to excellent" results were obtained in all five cases with pure disc herniation. In 25 of the 28 cases with associated secondary spondylosis. Two of the

Figure 2 Left Preoperative plain radiographs of the lumbar spine lateral view showing anterolisthesis of L5 on S1 vertebra with a dehiscence in L5 pars interarticularis (arrow) and degree retro-listhesis of L4 on L5 vertebra with an intact L4 neural arch. The contrast medium shows the extent of the slips. Right One year postoperative follow-up plain radiograph of the lumbar spine lateral view, showing no change in spondylolisthesis

operated upon previously, and who developed marked neurological deficits, and considerably, giving a "fair" result (most of cases) There was no mortality and morbidity was insignificant Spinal cord injury was significantly absent in this

DISCUSSION

In the lumbar articulated spine, the lumbar canal is bounded anteriorly by the posterior surfaces of the vertebral bodies and the intervertebral discs, and laterally by the pedicles and posteriorly by the superior elements which comprise the superior articular laminae and the spinous processes. Usually, the canal widens in the direction of the sacrum and is roughly pentagonal in shape. The normal antero-posterior diameter in the sagittal plane varies from 22mm to 25mm, with some being even larger. Certain individuals, however, have canals as shallow as 15mm or less (Ehni 1969a). The normal transverse diameter varies from 20mm to 25mm but in a developmentally narrow canal may be the antero-posterior diameter be 15mm but also the transverse diameter be 20mm. Herniation of a disc in such a position may produce symptoms distantly from the great and cause a cauda equina syndrome.

Common types of lateral disc herniation, compressing the adjacent lower root on the same side is seen, i.e. in the case of the fifth lumbar disc, the first sacral root is affected. In very severe cases of extreme lateral disc herniation, there is invasion of the intervertebral space, leading to compression of the corresponding segmental level. Disc herniation of sufficient size compresses the various roots of the cauda equina which emerge from the spinal canal at the level of the herniation, but this is not the case. Mono-radiculopathy is, therefore, a manifestation of lumbar disc herniation. Poly-radiculopathy or the cauda equina syndrome occurs in midline herniation of

sufficient size and also in cases of massive lateral disc herniation.

After a period of time, secondary structural changes occur in the lumbar spine. These changes are similar whether they be due to disc herniation, degeneration or resorption, i.e. reduction in the disc space leading to approximation of adjacent vertebral bodies. As a consequence, the posterior facet joint is stressed, overriden and undergoes a degenerative arthropathy, leading to hypertrophic bone formation around the joints (Harris & MacNab 1954). This leads to further reduction of the lateral recess and accentuation of the compression of the nerve root, already compressed by the disc. Overriding and displacement of the superior articular facet causes its encroachment into the foramen, leading to compression of the nerve root at the corresponding level. In addition, degenerative spondylolisthesis may occur in some cases and accentuate the compression (MacNab 1971). These structural changes, comprising a secondary spondylosis and segmental narrowing, explain the common occurrence of poly-radicular compression neuropathy in lumbar disc herniation. Narrowing occurs bilaterally, is more pronounced ipsilaterally, but is occasionally encountered also contralateral to the disc herniation. Prominent contralateral changes, when associated with pre- and post-fixation of nerve roots on the side of the disc hernia, may explain contralateral symptoms in disc herniation. Again, secondary spondylosis may be seen concomitantly with acute disc herniation, suggesting a more long-standing degenerative process (Friberg 1948, Munro 1956, Lewin 1964, Paine & Haug 1972).

A disc herniation in a primary, spondylolytic narrow canal may produce a cauda equina syndrome from multiple root involvement (Epstein et al. 1964). Further, disc removal through a limited interlaminar approach in such a situation may require excessive manipulation of the roots, causing oedema and thus accentuating the neurological lesion (Ehni 1969b). Diagnosis must ultimately depend on the detection of these structural

changes and also on the alteration of the characteristic pattern constructed by drawing lines to join the posterior aspects of the four articular facets of the lumbar vertebrae at the time of operation (McMinn & Hutchings 1977). In the first and second vertebrae, the figure is a vertical rectangle, in the third and fourth vertebrae the figure is square, and in the fifth a horizontal rectangle. In the presence of a single disc herniation, the characteristic shape is altered at that segmental level only, because the disc and the facet joints lie in the same horizontal plane. When there is a more generalized spondylosis, alteration of the normal appearances usually occurs at two or more levels. We believe this method has a sounder anatomical basis than the use of the stenosismeter (Verbiest 1975, 1977).

A wide laminectomy, including excision of the overhanging hypertrophied facet, is therefore the ideal procedure, as it allows gentle retraction of the nerve roots or cauda equina for exposure and removal of the disc hernia. Further, it permits careful examination of the nerve root up to its exit foramen and allows release of adhesions and foraminal decompression, whenever this is needed. Lastly, it ensures decompression of the already stenotic spinal canal in its lateral recess, a common occurrence in disc herniation (Paine & Haung 1972, Crock 1976).

It is a surgical axiom that adequate exposure is of the first importance in any procedure. This principle, we believe, should apply as much to the intervertebral disc lesion as to anything else. Full exposure achieved by wide laminectomy allows for an undamaged decompressed nerve root or cauda equina with minimal scarring and few, if any, postoperative problems. The limited and, in our view, inadequate exposure provided by the interlaminar approach is responsible for contused roots, extradural and peri-radicular haematoma, scarring and a wide variety of postoperative problems ranging from persistence of pain and invalidism to profound bilateral weakness of the legs and incontinence.

It has been argued that wide laminectomy causes spinal instability. We do not believe this and no case has been encountered in our series, this was evident by the time of clinical improvement in all cases in the absence of further slip in repeat roentgenograms in the three spondyloses. There are many recent reports (Paine & Haung 1972, Crock 1976, Hash 1976, Choudhury & Taylor 1977) supporting our view that instability does not occur. Gill & White (1965) and Gill (1970) have also found that removal of posterior elements in primary spondylosis does not cause vertebral displacement and it has been stated that spondylosis increases after the age of 20 years (Lämsä-Einola 1961, Wiltse 1962).

In conclusion it may be stated that cauda equina syndrome is a common manifestation in lumbar disc disease and is usually caused by structural changes in the spine. The wide laminectomy is a gratifying

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VENOUS DRAINAGE OF THE FEMORAL NECK A PROGNOSTIC SIGN IN PERTHES' DISEASE

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The correlation between delayed venous drainage from the femoral neck and "head at risk" factors were studied in 47 patients (50 hips) with Perthes' disease. A good correlation was found between markedly disturbed venous drainage and "head at risk" factors. Lateral subluxation of the femoral head and Gage's sign correlated best with pathological venography. Thus a severely disturbed venous return from a hip with Perthes' disease seems to be a poor prognostic sign.

Key words: hip, osteovenography, Perthes' disease, prognosis

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The outcome of Perthes' disease can be judged from plain radiograms of the hip at the time of clinical diagnosis (Eyring 1965, Catterall 1971, Dickens & Laus 1978). Catterall (1971) classifies Perthes' disease into four groups. Group one is the best and group four the worst prognosis.

He also lists some radiological signs which indicate an especially poor prognosis. These so-called "head at risk" factors are Gage's sign (which is a defect in the lateral part of the epiphysis), lateral subluxation lateral to the epiphysis, lateral subluxation of the femoral head and a laterally placed epiphyseal line.

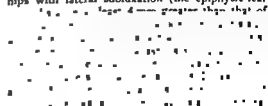
We have studied the venous drainage of the femoral neck in Perthes' disease since 1965. As our patients have been followed up for only 2 to 6 years until now, and since corrective osteotomies have been performed, it is probably influence the course of the disease, it is still too early to assess the final outcome. In this study an attempt is made to establish the prognostic value of intravenous venography of the femoral neck by

comparing the venographic findings with the "head at risk" factors. Because of the controversial reports on the significance of the horizontal epiphyseal line (Dickens & Menelaus 1978), this factor was not included in the study.

PATIENTS AND METHODS

The present material consists of 47 consecutive patients with recently diagnosed Perthes' disease. In three children both hips were affected. There were 36 boys and 11 girls. The age at the onset of the disease varied from 2 years to 10 years (average 6.9 years).

The "head at risk" factors were evaluated from anterior and Lauenstein lateral X-rays taken at the clinical onset of the disease. There were 29 hips with lateral subluxation (the epiphysis-tear



disease and before possible osteotomy, because this has an influence on the venous drainage. The pathological venographies were divided into two groups: slightly and markedly pathological according to the amount of contrast medium escaping via the femoral diaphysis compared with the amount escaping via the gluteal circumflex and obturator veins.

RESULTS

The proportion of each "head at risk" factor in normal, slightly pathological and markedly pathological intraosseous venographies is shown in Figure 1. Gage's sign was positive in only one of the 10 hips with normal venography, but was positive in 7/23 and 11/17 of the hips with slightly and markedly pathological venography ($P < 0.01$). The corresponding figures in cases of lateral calcification were 1/10, 6/23 and 7/17 ($P < 0.1$) and in lateral subluxation 3/10, 14/23 and 12/17 ($P < 0.01$). Thus the number of each "head at risk" factor increased with the severity of disturbance of the venous drainage of the femoral neck.

Figure 2 shows the number of "head at risk" factors in normal, slightly and markedly pathological intraosseous venography. Hips without risk factors were found in all groups but in 6/10 of the hips with normal

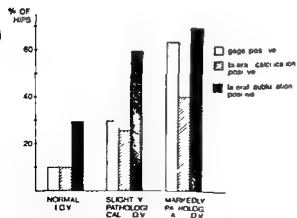


Figure 1 The proportion of each "head at risk" factor in hips with normal, slightly and markedly pathological intraosseous venography (i o v).

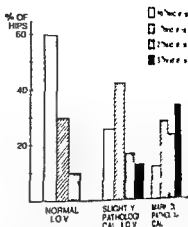


Figure 2 The number of each "head at risk" factor in hips with normal, slightly and markedly pathological intraosseous venography (i o v).

venography and in 6/23 and 2/17 with slightly and markedly pathological venography ($P < 0.001$). On the other hips with three "head at risk" factors not be found in hips with normal venography but in 3/23 and 5/17 of the hips with slightly and markedly pathological venography ($P < 0.05$).

DISCUSSION

It is well known that the prevalence of Perthes' disease varies with the age of the patient at the onset of the disease. Older children and girls have a better prognosis than boys and younger children. Neither the reason for these variations nor the basic etiological factors involved in the disease have yet been resolved.

Disturbances of the arterial and venous circulation of the femoral neck in Perthes' disease have been reported by Soto-Hall et al (1964), Soto-Hall (1972), Farine & Engel (1972), and Engel (1974). Contrast medium escapes from the bone marrow of the femoral neck mainly via the circumflex and obturator veins, and only a small amount through these veins in normal

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ARTROGRAPHY AS AN AID TO DIAGNOSIS, PROGNOSIS AND THERAPY IN 'LEGG-CALVÉ-PERTHES' DISEASE

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epiphysis was slightly larger (22) the same size (7) or smaller (10) than normal on the normal side, on arthrography the osteochondral head was much larger in 34 and the same size in 3 instances. In 35 cases the arthrograms

assessed the almost invariably poor head coverage in Legg-Calvé-Perthes disease, together with signs of flattening, diagnoses the severity of the disease process and helps to differentiate the "head at risk" which requires treatment. During arthrography the degree of abduction-medial rotation of the leg necessary for containment of the flattened protruding head within the acetabulum can be determined allowing accurate therapy to be planned, be it operative or orthotic.

Keywords: arthrography, diagnosis, Perthes, prognosis, therapy

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Diagnosis of Legg-Calvé-Perthes' Disease is made from two adequate radiographs, taken in the antero-posterior projection and in the Lauenstein (frog) projection (Fig. 1A-B). However, the limitations of plain film radiography are that the sizes of the osteochondral femoral head and acetabulum, their shapes and their relationships to one another cannot be accurately assessed, thus making the extent and severity of the lesion may be inadequately appreciated. It has been shown that arthrography gives the best opportunity for the assessment of a spherical head at the end of the maturation process (Axer 1965, Harrison

et al 1969, Petrie & Bitenc 1971, Axer et al 1973, Curtis et al 1974, Brotherton & McKibbin 1977, Salter et al 1977). The problem is to assess the degree of rotation of the femur (or pelvis) required to achieve adequate containment. This paper describes how these diagnostic, prognostic and therapeutic questions can be resolved by performing bilateral hip arthrography before deciding on treatment.

PATIENTS AND METHODS

Prior to arthrography, radiographs of the hips of all children were made in the standard neutral and



Figure 1 Six year old boy with right sided Legg Calvé Perthes' syndrome in the early fragmentation stage A and B Plain radiographs in antero-posterior and Lauenstein projections The right femoral head appears slightly smaller than that on the left C Arthrogram in antero-posterior neutral projection The right osteochondral head is in fact larger than that on the left and is flattened in the region under the lateral acetabular lip The head protrudes laterally but still maintains contact with the acetabulum medially D Arthrogram with the hips abducted and medially rotated The osteochondral head will be completely contained by the acetabulum on further slight abduction

Lauenstein positions Bilateral hip arthrography was performed in 37 consecutive children suffering from unilateral Legg-Calvé-Perthes' Disease Radiographs of both hip joints were then taken with the hips in neutral position (Figure 1C) in an abducted medially rotated position (Figure 1D) and in the Lauenstein position Prior measurements of antevers (Dunlap et al 1953



$$\frac{A}{B} \times 100 = \text{ACETABULUM HEAD QUOTIENT}$$

$$\frac{\text{Abnormal Side Index}}{\text{Normal Side Index}} \times 100 = \text{Acetabulum Index}$$

Figure 2 The Acetabulum-Head Quotient

Axer et al 1972) were helpful in determining much medial rotation should actually be formed

The following measurements and observations were made on both hips of a patient using the plain radiographs and arthrograms

- 1 The widest diameter of the head in neutral and Lauenstein views was measured
- 2 The acetabulum head acetabulum head quotients (Figure 2, Herndon 1950) were measured and compared the plain radiographs and on the made in the neutral position
- 3 Observations were also made on arthrograms for deformities of the femur and pooling of contrast material

RESULTS

The results of the above measurements and calculations are shown in Table 1. 10 cases of LCPD were either necrotic (22 cases) or in the fragmentation stage (15 cases)

1 Head diameters

Radiographs A difference in the diameter of the femoral heads between the two hips of 1 mm or more was recorded in 10 cases (Schiller & Axer 1972). Of the 15

heads 22 were larger, 9 were the same, 4 were smaller and 2 were 1 mm or more and 1 mm smaller in the other than as compared with the femoral head on the opposite unaffected side

Arthrograms Thirty-four affected femoral heads were from 1 to 17 mm larger than the opposite normal femoral head (Figure 1C), the remaining 3 were the same size as the opposite unaffected femoral head

Table 1 Roentgenographic measurements and observations

Stage	Head diameter difference in mm				A. H. Q.		Flattening
	Regular		Arthrography		Regular	Arthrog raphy	
	A. P.	Frog	A. P.	Frog			
N	0	2	2	0	100	90	+
N	0	1	0	0	100	88	+
N	-0.5	-0.5	0	0	85	79	+
F	-1	-2	1.5	1.5	85	70	+
F	0	0	1.5	2.5	100	89	+
F	0	-1	2.5	2	90	72	+
F	0.5	0	2	2	95	90	+
N	0	0	2.5	4	97	89	+
F	6	6	*	6	85	*	+
N	0	0	1.5	3.5	100	90	+
N	-1	-1	4	2	100	81	+
F	10	11	15	17	79	75	+
N	2	3	7	6	100	79	+
F	5	10	8	5	89	82	+
N	-1	1	3	4	100	93	+
N	2	2	5	5	98	95	+
F	3	4	5	6	99	92	+
N	1	0	3	2	100	82	+
N	0	0	3	3	90	77	+
N	1	1	2	4	100	79	+
F	2	2	5	7	92	89	+
N	0	0	4	3	93	81	+
F	2	1	5	4.5	88	85	+
F	3	2	4	5	98	92	+
F	5	7	6	6	82	82	±
F	0	0	3	3	78	80	+
N	1	1	2	3	93	94	+
N	1	-1	5	5	100	89	+
N	2	2	7	5	100	90	+
N	3	0	4	4	95	76	+
F	8	7	12	10	72	79	+
F	4	1	4.5	5	81	79	+
N	1	0	8	3	81	78	+
N	0	1	2	2	100	91	+
N	0	-2	0	0	100	95	+
N	1	1	1	1	100	88	+
F	1	0	2	2	100	95	-

possible to measure
led L.C.P.S. on other side 5 years previously
non-operated cases.
crotic
segmentation.

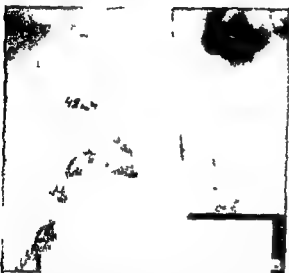


Figure 3 Seven year-old boy with right sided Legg Calvé-Perthes' syndrome in the necrotic stage A Arthrogram in the antero-posterior neutral projection The osteochondral femoral head is enlarged, protrudes laterally from the acetabulum and is markedly flattened in the region under the lateral acetabular lip B Arthrogram with the hip abducted and medially rotated The flattened region of the head with the pool of contrast material above it is now rotated into the depths of the acetabulum

2 Acetabulum-head quotients

In the 37 children with Legg-Calvé-Perthes' Disease the quotient calculated from the arthrographic measurement was less in 34 cases, in one case equal to, and in one greater than the same quotient calculated from the

plain radiograph. (One case only measured)

3 Observation on the arthro-

Flattening of the area of the aspect of the osteochondral head... the lateral acetabular lip was absent present in 35 of the 37 femoral heads by Legg-Calvé-Perthes' Disease (Fig. 1 and 3A) On the abduction and rotation arthrogram the flattened head now faced the concave and central area of the acetabulum, and it up with contrast material (Figure 3B)

DISCUSSION

Arthrography of the hip joint was in the present series firstly because that while the diameter of the femoral head on the affected side as estimated on the plain radiograph, was slightly greater on the opposite side in 22 cases (59%) and in the remaining cases was the same or smaller, the osteochondral femoral diameter, as measured by arthrography, revealed that in 34 cases (92%) the affected head was in fact markedly smaller than that on the opposite normal side. In the remaining 3 cases the size of the affected head was the same as the unaffected one. It is obvious that the acetabulum is also be greater, since the femoral head sublux from the acetabulum even maintained between the acetabulum and the medial side of the joint as shown in Figures 1C-D and 3A-B

Arthrography was also demonstrating that in 35 out of 37 affected femoral head was not only flattened but was also flattened on the superior aspect of the chondral surface even in the early and fragmentation stages of the disease process. In the necrotic stage

area was situated directly under the acetabular lip (Figures 1C and 3A) & Bell (1973) and McKibbin & Ralis (1977) by direct arthroscopic examination of the hips of children with Legg-Calvé-Perthes' Disease noted areas of head flattening in all cases and cartilage fibrillation over a portion of the femoral head in two of the hips examined. In two cases recorded a definite defect in the head opposite the lateral acetabular lip. This suggests that it is the lateral acetabular lip which 'ploughs' into the articular surface of the enlarged femoral head (Lunn 1974) and causes the flattening. We have also experimental evidence for this flattening in an animal model where, by the induction of a synovitis in the hip joint of young rabbits, the osteochondral femoral head was stimulated to enlarge. The heads developed a flattened, degenerative area of cartilage under the lateral acetabular lip (Lunn & Axer 1974, Gershuni et al 1978).

If the chondral flattening and osteochondral separation is caused by the 'ploughing' of the lateral acetabular lip it seems reasonable to remove it from further abnormal contact by rotating it into the depths of the acetabulum proper where regeneration and healing of the immature cartilage will occur (Salter et al 1977, Gershuni et al 1978). The necessity for this procedure is suggested by examination of the arthrogram which will demonstrate the presence and extent of the chondral flattening.

The acetabulum head index gives a measure of the containment of the femoral head by the acetabulum, and the acetabulum head quotient compares the containment of the diseased femoral head with that of the normal side. In 34 out of 37 cases the acetabulum head quotient measured on the arthrogram was less than that measured on the plain radiograph. Thus it is apparent that the femoral head coverage and containment on the arthrogram is rather optimistically assessed when studying plain radiographs. An antero-laterally protruded head cannot be

molded by the acetabulum and is thus at risk, attainment of a spherical head at the end of the disease process in such a case is unlikely. A poor result would then be anticipated when no containment treatment is given, be it surgical or orthotic. In two children (nos 36 and 37, Table 1) no significant antero-lateral protrusion of the head was defined by the arthrogram taken in the neutral position and the acetabulum-head quotient as calculated from the arthrogram was not significantly different from that calculated on the plain radiograph. These two children have not been treated but are being continually observed and periodically examined radiographically, so far their results have been gratifying. The remaining 34 children, according to the arthrographic assessment required containment treatment and underwent femoral derotation varus osteotomy (Axer 1965, Axer et al 1973, 1979).

When containment therapy is decided upon the degree of abduction and medial rotation of the femur needed to rotate the protruded and flattened segment of the head to within the confines of the acetabulum can be measured by correlating the position of the femur with the arthrographic appearance (Figures 1D and 3B). The correct degree of varus-derotation femoral osteotomy can thus be tailored to the needs of the individual case. Arthrography in these young children has always been performed in the operating theater under general anesthetic. If operation is decided upon, this proceeds with continuation of the same general anesthetic and after redraping the part (Axer et al 1979). Alternatively another method of containment therapy may be used (Harrison et al 1969, Petrie & Bitenc 1971). In such a case the knowledge gained from the hip arthrography may be applied in a similar fashion, when using femoral osteotomy, in more precisely planning treatment.

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INCIDENCE OF HIP FRACTURES

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as prevalent in females as in males and the incidence was found to double for each 5 year increment in age. The percentage of femoral neck fractures decreased with age in females but was constant in males.

Key words: epidemiology, femoral neck fractures, occurrence, fractures, occurrence, hip fractures

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Incidence of hip fractures has been the subject of a limited number of studies. In 1964, Bauer 1960, Buhr & Cooke 1964, Gallanaugh et al 1976, Knowelden et al 1974, Mårtensson 1962, Nilsson & Obrant 1978, Stewart 1955, 1958). However, the incidence of fractures has been increasing considerably during the past 20 years.

Ham (1964) claimed that the number of hip fractures was increasing more than would be expected from the age distribution of the population, but Nilsson & Obrant (1978) suggested that this tendency to vanish in the late

of 78 years, whereas the mean age in males was 74 years.

In the suburban area studied there was a total of 530 729 persons over 50 years of age resident during the 6-year period. The number of elderly people increased slowly during the observation period.

The patients were subdivided into age groups with 5 year increments and also according to sex and fracture type. The population of the area was similarly subdivided into age and sex groups according to information obtained from the Danish Central Bureau of Statistics. From these data the incidence of hip fractures was calculated and analysed by a multiplicative Poisson model (Andersen 1977).

The present study deals with the incidence of hip fractures in a suburban area in the

RESULTS

The incidence of hip fractures did not change significantly during the 6-year period. As shown in Figure 1 the incidence of hip fractures increased exponentially with age from the beginning of the 7th decade. The sex ratio women/men was 1.99 and the incidence approximately doubled with each 5-year increment in age.

RESULTS AND METHODS

During the period April 1st, 1971 to March 31st, 1977, a total of 1,598 patients over the age of 50 were admitted to hospital with hip fractures. Of these, 762 (1 598) were femoral neck fractures were encountered in 477 patients (762/1 598) and trochanteric fractures in 523 per cent (836/1 598), 76.7 per cent (225/1 598) were females with a mean age

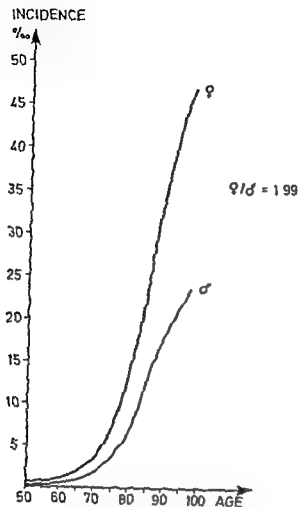


Figure 1 The incidence of hip fractures in the northern suburbs of Copenhagen during the years 1971-1976

The total incidence of hip fractures among females over the age of 50 years was about 4 per thousand compared with about 2 per thousand in males. The overall incidence was thus about 3 per thousand above the age of 50 years, while it was about 20 per thousand above the age of 80 years.

The distribution between femoral neck fractures and trochanteric fractures was analysed in relation to age and sex as shown in Figure 2. The percentage of femoral neck fractures in females decreased with age and was almost halved from the 5th to the 9th decade, whereas the percentage in males was rather constant and independent of age

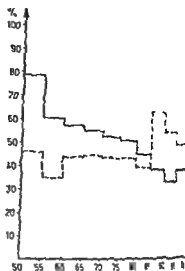


Figure 2 The percentage of femoral neck fractures in relation to age and sex

DISCUSSION

The incidence of hip fractures was about 3 per thousand above the age of 50 years, which accords fairly well with studies (Gallanagh *et al.* 1972), but is about double the rate reported in the 1950s (Burr & Cole Stewart 1955, 1958).

Bauer (1960) found the incidence to increase for each 5 year increment in age, which was confirmed by Gallanagh *et al.* (1972). Knowelden *et al.* (1964) as well as the present series. The exponential increase in hip fractures in the elderly was paralleled by the number of deaths among elderly people (Locht 1971).

It has been stated by Alfrim (1960) that the number of hip fractures has increased to a greater extent than expected from the age and sex distribution of the population. The incidence of hip fractures presented in this series accords with recent studies (Gallanagh *et al.* 1972), somewhat higher than in studies from the 1960s (Bauer 1960). The incidence was about twice as high as in the beginning of the 1950s (Burr & Cole Stewart 1955, 1958). Compared with Alfrim's series (1960), the incidence was about twice as high.

similar figures until the age of 75 years, considerable increase for the oldest age groups. The observations by Nilsson & Obrant that the incidence has not changed since the 1960s can thus not be confirmed although the geographical areas concerned in our series are fairly similar. As about half of the patients sustaining hip fractures are above the age of 80 years it is suggested that the incidence figures for the oldest age groups should be updated approximately every 10 years in order to provide a realistic basis for the planning of the hospital care of patients with hip fractures.

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INCIDENCE

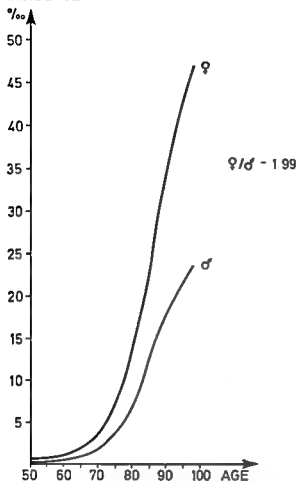


Figure 1 The incidence of hip fractures in the northern suburbs of Copenhagen during the years 1971-1976

The total incidence of hip fractures among females over the age of 50 years was about 4 per thousand compared with about 2 per thousand in males. The overall incidence was thus about 3 per thousand above the age of 50 years, while it was about 20 per thousand above the age of 80 years.

The distribution between femoral neck fractures and trochanteric fractures was analysed in relation to age and sex as shown in Figure 2. The percentage of femoral neck fractures in females decreased with age and was almost halved from the 5th to the 9th decade, whereas the percentage in males was rather constant and independent of age.

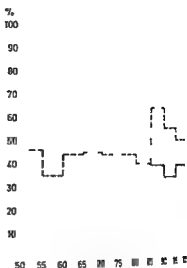


Figure 2 The percentage of femoral neck fractures in relation to age and sex

DISCUSSION

The incidence of hip fractures was found to be about 3 per thousand above the age of 50 years, which accords fairly well with studies (Gallanaugh et al. 1976, G. 1972), but is about double the rate reported in the 1950s (Buhr & Cochrane Stewart 1955, 1958).

Bauer (1960) found the incidence to increase for each 5-year increment in age, which was confirmed by Gallanaugh et al. (1976) and Knowelden et al. (1964) as well as by the present series. The exponential increase in hip fractures in the elderly was paralleled by the number of deaths among elderly people (Lucht 1971).

It has been stated by Allfram (1966) that the number of hip fractures during the last 10 years has increased to a greater extent than was expected from the age and sex distribution of the population. The incidence of hip fractures presented in this series agrees well with recent studies (Gallanaugh et al. 1976) but is somewhat higher than in studies from the 1960s (Bauer 1960, Mårtensson 1966) and about twice as high as in studies from the beginning of the 1950s (Cochrane & Stewart 1955). Compared with Allfram's series (1966),

DIAGNOSTIC EVALUATION OF THE HOSPITAL RESOURCES REQUIRED FOR THE TREATMENT OF HIP FRACTURES

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A retrospective study of 1,592 hip fracture patients over the age of 50 years was undertaken, recording the age and sex, the fracture type and treatment, the hospitalization time and the rate of technical failures.

Based on the predicted population in the area of admission it was calculated that the number of hip fractures will double within the next 17 years.

An analysis of the hospitalization time in relation to the various types of treatment and the rate of technical failures made it possible to calculate the hospital resources required in the future. It was found that despite the considerable increase in the number of hip fractures treatment can be undertaken without further allotment of resources provided a rationalized treatment plan is instituted aiming at the safest possible methods of treatment, as the hospitalization time was found to be considerably influenced by technical failures of the treatment.

Key words: femoral neck fractures, hospitalization, internal fixation

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The average age of the population in the industrialized countries is increasing and in recent years it has been shown that the incidence of hip fractures is increasing exponentially with age, so that the incidence doubles for every 5-year increment in age after the age of 50 (Bauer 1960, Gallanough et al. 1962, Jensen 1980). The increasing number of elderly people in the population involves an increasing number of hip fractures, this being one of the most common conditions in orthopaedic medicine.

Although the health systems in the industrialized countries are facing the effects of the current economic crisis with reductions in expenditures for hospital care little attention has been paid to the consequences of the increasing

number of hip fractures (Gylling 1960, Lindberg & Sjøstrand 1972, Mårtensson 1962).

The purpose of the present study is to estimate the hospital resources required in the future and to find a reasonable economic solution for the problem of the treatment of an increasing number of hip fractures.

PATIENTS AND METHODS

During the period April 1st, 1971 to March 31st, 1977 a total of 1,592 patients over the age of 50 years were admitted to hospital with hip fractures. Femoral neck fractures were recorded in 47.5 per cent of the cases (756/1,592) and trochanteric fractures in 52.5 per cent (836/1,592).

Table 1 The background population (over 50 years of age) in the area of admission during the 6-year period 1971-1976

	1971	1972	1973	1974	1975	1976
Original area of admission	83,257	84,720	86,315	87,908	89,065	90,661
Extension of area					1,803	1,803
Total	83,257	84,720	86,315	87,908	90,868	92,464

The background population consisted of 530,729 persons, over the age of 50 years, resident in the area of admission during the 6-year period. As seen from Table 1, the background population increased from 83,257 persons in 1971 to 97,661 persons in 1976. On January 1st, 1976 an extra municipality was added to the area of admission, which involved a recruitment of 7,609 persons in the final year of the observation period. The yearly increase in the background population was 8 per cent (6,795/83,257) corrected for the increased area of admission.

A retrospective study was undertaken recording the age and sex of the patients, the type of fracture, the type of treatment, the hospitalization time and the number of technical failures for each year of the period.

From the Danish Central Bureau of Statistics the expected number of inhabitants over 50 years of age for all the municipalities of the area of admission was obtained for every year until March 31st, 1992. The expected background population for each year is recorded in Table 2.

Table 2 The expected background population (over 50 years of age) for the extended area of admission during the years 1977-1991

	Number of inhabitants	Yearly increase
1977	98,370	+709
1978	99,265	+895
1979	99,821	+556
1980	100,394	+573
1981	100,624	+230
1982	100,777	+153
1983	100,821	+44
1984	100,847	+26
1985	100,802	-45
1986	100,695	-107
1987	100,641	-54
1988	100,614	-37
1989	100,466	-148
1990	100,388	-78
1991	100,261	-127

Based on these data and on previous studies of the incidence of hip fractures according to sex in the area (Jensen 1980) a predicted number of hip fractures could be made. Calculations regarding the expected background time were made taking into account the technical failures of the fracture treatment.

RESULTS

The number of patients admitted during each year of the period is shown in Figure 1. The total number of hip fractures increased from 221 in 1971 to 343 in 1977. For the extra municipality included in the last 2 years of the period, the yearly number of hip fractures was 8 per cent (17/221) or a total of 47 per cent.

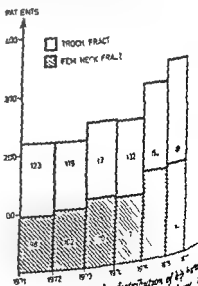


Figure 1 The yearly distribution of hip fractures in 1,592 patients admitted during the period 01-04 1971-31-03 1977

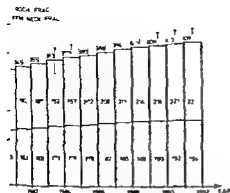


Figure 2 Predicted number of hip fractures in the admission for the period 1979-1992

increase in the number of trochanteric moral neck fractures did not differ antly ($P = 0.76$, Chi-square test). d on the expected composition of the tion of the area and the calculated ice of hip fractures a prediction of the r of hip fractures for the period 1992 was made. Figure 2 demonstrates calculated figures including the 95 per onfidence limits.

omparison with the 221 hip fractures in a doubling of the number might be ed from about 1988 within the nce limits stated. Thus, the number of ctures is expected to double within a of 17-26 years. As seen from the m a yearly increase in the number of

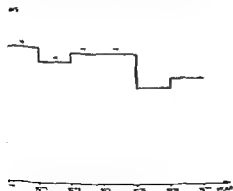


Figure 3 The average hospitalization time for hip fractures in 1592 patients admitted during the period 1971-1977

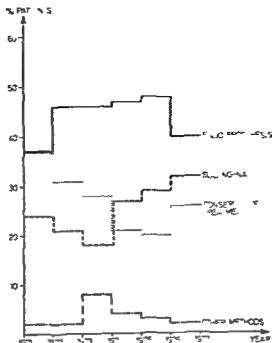


Figure 4 The methods of treatment of femoral neck fractures in the period 1971-1977

hip fractures of about 3 per cent is predicted in the beginning of the period, but due to stagnation of the population increase - as seen in Table 2 - the yearly increase drops to about 1.5 per cent in the latter part of the period. The confidence limits, however, allow yearly increases of about 11-13 per cent.

During the observation period the hospitalization time for patients with hip fractures decreased from 28 days in 1971 to 22 days in 1976, as shown in Figure 3. The number of hospital beds occupied by patients with hip fractures thus only increased from 17 beds in 1971, equivalent to 6,183 hospital days, to 21 beds in 1976, equivalent to 7,546 hospital days, due to the reduction in hospitalization time. This also means that about 18 per cent (21/118) of all orthopaedic hospital beds in the area were constantly occupied by this category of patients in 1976.

Supposing the hospitalization time will be 21 days on average, as it was in the last 2 years of the observation period, the 372 patients (range 334-410) expected in 1984

Table 3 Hospitalization time in relation to type of treatment and technical failure of femoral fractures

	Uneventful course	Hosp. time (days)	Technical failure (%)	Technical failure (%)
Femoral Neck Fractures				
sliding-nail	144	20.6	51 (35%)	1
conservative treatment	175	18.3	2 (1%)	1
endoprosthesis	318	23.3	15 (4%)	1
other methods	17	23.2	9 (5%)	1
Trochanteric Fractures				
McLaughlin	396	20.7	47 (12%)	2
Jewett	243	28.1	15 (6%)	1
sliding screw-plate	85	23.3	2 (2%)	1
conservative treatment	37	19.6	0	1
other methods	9	24.6	6 (6%)	1

will require 22 hospital beds (range 20–24) and in 1969 the corresponding figures will be 408 patients (range 368–448) needing 24 beds (range 22–26), equivalent to 19 and 20 per cent of all hospital beds, respectively. The yearly consumption of hospital days will be

7,812 in 1984 and 8,058 in 1989. These calculations presuppose an unchanged pattern of fracture treatment.

With the purpose of finding out to what extent extra hospital days could be prevented, the increasing demand for an analysis of the treatment of the femoral neck fracture was undertaken. In Figure 4 the treatment of femoral neck fractures is demonstrated. It is seen that endoprosthesis, i.e. hemiarthroplasty, is constantly applied in about 44 per cent (334/756) of cases. Conservative treatment, i.e. early weight-bearing, has decreased during the 6-year period to about 39 per cent (18/95) in 1971 and 26 per cent (42/162) in 1976. Endoprosthesis fixation by a sliding-nail method was applied in 22 per cent (22/95) in 1971 and 22 per cent (52/162) in 1976. As seen from Table 3, the average hospitalization time was significantly shorter ($P < 0.001$, Mann-Whitney test) for the uneventful course of treatment than for the cases with technical failures. About 11 extra hospital days were needed on average for these cases. It is also seen that the number of technical failures following sliding-nail fixation is about 26 per cent compared with 13 per cent for conservatively treated cases. Technical

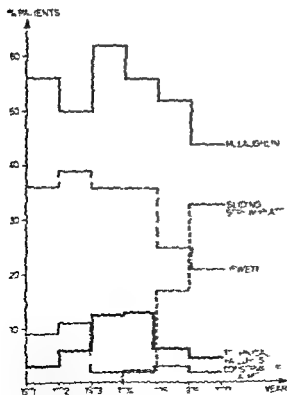


Figure 5 The methods of treatment of trochanteric fractures in the period 1971–1977

neck fractures led to secondary theses.

changes in the methods of treatment

interic fractures are demonstrated in

It is seen that nearly all these

were internally fixed. The sliding

ate was introduced in 1974 and was,

ad of the period, applied in about 33

(59/181) of cases. Due to this the use

Jewett and McLaughlin hip nail-plates

d considerably and at the end of the

hese two types of nail-plates were

ed in 70 per cent (37/181) and 44 per

1/181), respectively, of trochanteric

The sliding screw-plate was

y introduced for the treatment of

trochanteric fractures and resulted in

ed reduction in the frequency of

failures, as also seen from the

Technical failures after internal

of trochanteric fractures were

by re-osteosynthesis. According to

technical failures were encountered in

cent of cases (42/438), on average,

McLaughlin osteosynthesis

d with 6 per cent (15/258) after

osteosynthesis and 2 per cent (2/88)

sliding screw-plate fixation,

the latter method was applied in

fractures and followed by early

earing mobilization. It can also be

in Table 3 that the hospitalization

s considerably prolonged in the case

nical failures ($P=0.0001$, Mann-

test)

effects on hospitalization time of

l failures and the modern trend of

te weight-bearing mobilization in all

as applied during the latter 2 years of

rvation period, were further analysed.

ral neck fractures the hospitalization

lowing sliding-nail fixation has been

ng constantly during the 6-year

rom about 30 days to 18 days. Similar

were encountered following primary

throplasty or non-operative treatment.

efore assumed that the following ideal

ization times will be obtained in un-

complicated cases within a couple of years

sliding-nail fixation 16 days, hemiarthroplasty

18 days and conservative treatment 12 days.

We also assumed that the pattern of

treatment in the future will be unchanged and

will include 30 per cent sliding-nail fixation,

45 per cent primary hemiarthroplasty and 25

per cent conservative treatment. Finally we

assumed that the number of technical failures

will be unchanged as will hospitalization

times after technical failure, as seen in Table

3.

With these assumptions in mind the yearly

consumption of hospital days was calculated.

In 1984 the number of femoral neck fractures

was expected to be 175 and the consumption

of hospital days 3,184, compared with 190

patients and 3,431 days, respectively, in 1989.

Thus the number of hospital beds needed for

the treatment of femoral neck fractures would

be an average of 9 in 1984 and 10 in 1989. As

it has not been possible so far to find

methods which involve a lower frequency of

technical failures, we consider the required

number of hospital days as stated to be a

rather realistic estimation. With the high

frequency of technical failures following

internal fixation with sliding nails considera-

tion should be given to applying primary

hemiarthroplasty in patients physiologically

younger than the 75 years which has been the

limit up to date. In the case of a change in

the pattern of treatment so that sliding-nail

fixation was used in 25 per cent of cases and

primary hemiarthroplasty in 50 per cent,

which involves altered treatment in only 5 per

cent of cases, 27 hospital days could be

gained in 1984 and 5 days in 1989. This

means that less than 1 per cent of the

hospital days could be saved by an alteration

of the treatment in 5 per cent of cases.

The hospitalization time following internal

fixation of trochanteric fractures with the

McLaughlin nail-plate has been fairly

constant over the years being about 21 days

in uncomplicated cases, while the hospitaliza-

tion time has decreased from 34 days to 17

days following Jewett nail-plate fixation due

to the introduction of the sliding screw-plate system for unstable trochanteric fractures. The average hospitalization time following sliding screw-plate fixation has been 23 days. We expect the ideal hospitalization time in uncomplicated cases in the near future to be 21 days for McLaughlin cases, 17 days in Jewett cases and 21 days after sliding screw-plate fixation. Assuming a pattern of fracture treatment as in 1976 with McLaughlin fixation in 46 per cent, Jewett in 20 per cent and sliding screw-plate in 34 per cent of cases, and hospitalization times as mentioned above and in Table 3, with an unchanged frequency of technical failures, the yearly consumption of hospital days was calculated. In 1984 the number of trochanteric fractures is expected to be 197 and the consumption of hospital days 4,177 compared with 218 patients and 4 636 days in 1989. Thus the number of hospital beds needed for the treatment of trochanteric fractures would be an average of 12 beds in 1984 and 13 beds in 1989.

As mentioned above the sliding screw-plate system was introduced in 1974 for the treatment of unstable trochanteric fractures and has reduced the frequency of technical failures considerably. Assuming that all unstable trochanteric fractures in the future will be treated by this fixation system, with unchanged hospitalization time and technical failure rate, we would expect 70 per cent of fractures to be fixed by this method. The application of Jewett or McLaughlin nail plates in stable fractures is expected to be unchanged, which means 11 and 19 per cent of cases, respectively. The hospitalization time is assumed to be the same for these two methods, i.e. 17 days, as well as the technical failure rate of 5 per cent (Jensen & Michaelsen 1975). With these assumptions the yearly consumption of hospital days could be calculated to be 3 987 days in 1984 and 4 404 days in 1989, which means that about 5 per cent of the hospital days could be saved by altering the pattern of fracture treatment and concentrating on using safer methods.

DISCUSSION

The number of elderly people in the population has been increasing over the years (Boucher 1959, Blair & Cole 1962, Martenson 1962), but

prognosis this trend will change in suburban areas during the last 10 years.

According to Boucher (1959) about a third of all beds in American hospitals are occupied by old people. Lucht (1971) found that about 70 per cent of domestic falls in elderly people result in fractures.

Hip fractures in elderly people are a rather serious problem in many countries, and prognostic evaluations are necessary for the future planning of orthopaedic wards.

In the present series we found a marked increase in the number of hip fractures during the period 1971-1976, about 100 per cent assuming a uniform increase in the background population. As in previous studies (Alffram 1964, Lindberg & Sjöstrand 1962, Martenson 1962) we have only observed a yearly increase of about 2-3 per cent. This is in contrast to the stagnation of the population, and thus reckoning the number of hip fractures can be expected to double within a period of about 17 years, which agrees with recent observations (Alffram 1964, Blair & Cooke 1959, Falch & Leibel 1964, Gallanagh et al. 1976, Martenson 1962).

Gylling (1960) stated that the number of hip fractures is consuming an increasing portion of the total number of hospital beds, which can be confirmed by our present study. In the evaluation of future needs it is very important to consider the average hospitalization time. In former series (Alffram 1964, Gylling 1960, Martenson 1962) the average hospitalization time was about 30 days, but has decreased enormously during the last 10 years to about 20 days (Gallanagh et al. 1976, Lindberg & Sjöstrand 1972). In the present series a further reduction in the hospitalization time has been encountered.

ing of the 1970s so that in the period 1976 it was about 21 days. This is mainly due to more active mobilization, encouraging early mobilization and weight-bearing. It is of course very difficult to predict the future hospitalization time for the treatment of hip fractures, as this is due to a great extent to the possibility of discharging patients to rehabilitation institutions. In the present series we have estimated the ideal hospitalization time in uncomplicated cases to be about 12 days for non-operatively treated femoral neck fractures, about 16–18 days for femoral internal fixations and primary total hip replacement and about 21 days for the treatment of unstable trochanteric fractures. We are convinced that these estimates are fairly realistic considering we are dealing with elderly patients with an average age of about 77 years (Jensen 1980). In our opinion the economic crisis in the health services in the Western countries makes that a further allotment of resources for hospital or rehabilitation institutions cannot be expected. We will therefore be forced to look for ways of solving the problem of treating the increasing number of hip fractures using the minimum number of hospital beds in the already established orthopaedic units. It is not easy to predict the number of hip fractures according to the population projection, but the hospital resources required are determined by the trends in hospitalization following the different methods of treatment. The most essential factor to consider is the frequency of technical failures, as these are followed by a considerably prolonged hospitalization time – in the present series about 21 days. We agree with Gallanaugh et al (1976) that it is of utmost importance to evaluate the fracture treatment and apply the best possible methods. In our opinion a reduction in the consumption of resources can be attained by applying internal fixation in femoral neck fractures in younger, mobile patients only and using sliding screw-plate fixation in unstable trochanteric fractures, as

this will reduce the number of technical failures considerably.

In the present series a total of 7,546 hospital days were needed for the treatment of hip fractures in 1976. The hospital resources required in the future were evaluated by three different methods. The simple estimation of hospital days based on the expected number of patients multiplied by an average hospitalization time of 21 days (as encountered during the last 2 years of the observation period) involved a consumption of 7,812 hospital days in 1984 and 8,568 hospital days in 1989. By comparison, the calculations based on unchanged treatment methods and unchanged failure rates but gradually decreasing hospitalization times, following the trend throughout the observation period, led to a consumption of 7,361 hospital days in 1984 and 8,067 days in 1989, which is about 6 per cent less than the first calculation. The third prediction included an alteration in the methods of treatment with preference for the safest methods with a minimum of technical failures. These calculations gave a further reduction of hospital days to 7,144 days in 1984 and 7,830 days in 1989, or a gain of about 2.5–3 per cent.

Considering the economic aspects of the future hospital treatment of orthopaedic diseases we feel that it is very important to perform the prognostic evaluations of the hospital beds required in the future on the basis of a rational approach to the treatment applying the safest possible methods. In the examples presented it is thus possible to treat about a 15 per cent increase in the number of patients with hip fractures using the same resources as were consumed in 1976 by such alterations in the attitude to the treatment, and thereby to keep up with the increased influx of patients without demanding further resources.

In conclusion, we found that the number of patients with hip fractures admitted to hospital will double within a period of about 17 years, but that the treatment can be

undertaken with unchanged demands on hospital resources by rational planning aiming at the safest possible methods of treatment, as the hospitalization time is considerably influenced by technical failures of the treatment.

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OSTEOARTHRITIS OF THE HIP

iology and Clinical Role

JØRRING

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Among 6321 patients who had undergone X-ray examination of the hip 47 per cent proved to have osteoarthritis of the hip. A mild osteoarthritis was found to be equally common in both sexes, but in all age groups above 60 severe osteoarthritis of the hip was twice as common in women as in men.

troublesome than the lateral

According to the present study, only half the patients who exhibit radiological changes of the hip are troubled by symptoms.

Key words: osteoarthritis of the hip, clinical role, epidemiology, need of treatment

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accordance with clinical experience, a radiologist, when examining for other conditions, will frequently come across patients with obvious osteoarthritis of the hip without their having had any complaints or mentioning it. The same applies to the other joints as has been pointed out previously by Lawrence et al 1966, and Schmorl and Junghans 1932. However, although radiologically demonstrable osteoarthritis of the hip has often been reported to occur (Lawrence 1949, Danielsson 1966) no one has previously demonstrated how large a proportion of these patients are symptom-free. The present investigation was designed to provide a randomized material of patients with radiological osteoarthritis of the hip in order to study the epidemiology and

the social significance as well as the clinical features of the osteoarthritis.

PATIENTS AND METHODS

An X-ray examination of the hip includes at least one anteroposterior view of both hip joints and several oblique views. On the basis of such an examination, therefore, it is possible to decide whether radiological signs of osteoarthritis of the hip are present. As it is reasonable to assume that no relationship exists between colonic diseases and osteoarthritis of the hip joints, the choice of patients referred for X-ray examination of the hip can be regarded as a random selection - in relation to osteoarthritis of the hip.

As a criterion of osteoarthritis narrowing of the joint space to 3 mm or less was chosen. This distance is arbitrary (Goffin (1979) and Köhler

(1956) chose the same distance — 3 mm — as an expression of cartilaginous narrowing in X-rays of the hip joint.

A cartilage thus reduced was an isolated finding in two women aged 50 while in others it was associated with sclerosing of the subchondral bone and/or subchondral cyst formation and/or osteophytes. Sclerosing with cysts or osteophytes without joint space narrowing was not observed. Osteophytes situated exclusively at the lateral edge of the acetabulum were not interpreted as a sign of osteoarthritis (Brailsford 1952, Danielsson 1964). Likewise, sclerosing without a reduced depth of cartilage was not interpreted as osteoarthritis. Isolated cyst formation was not observed.

A radiological classification of the osteoarthritis was performed according to Kellgren (1963), who has suggested a radiological classification into four grades and hanging up in the viewing room a typical representative of each. A given film, then, belongs to the grade to which it is most similar.

During the 10-year period, 1963–1972 inclusive, a total of 6360 patients underwent X-ray examination of the colon in the Copenhagen City Hospital. All the films were reviewed to detect osteoarthritis of the hip. In 6321 of the patients the hip joints could be assessed, but 39 patients had to be excluded, as their hip joints were not satisfactorily visualized.

The material did not include many patients under 25 years of age, but it has previously been demonstrated that osteoarthritis hardly ever occurs in children or young adults.

RESULTS AND DISCUSSION

Prevalence of osteoarthritis of the hip

Among the 6321 patients, 299 proved to have osteoarthritis of the hip. This is a prevalence of 4.7 per cent. In women the rate was 5.6 per cent, in men 3.7 per cent, i.e. a female:male ratio of 3:2.

Osteoarthritis was sporadic prior to the age of 50 years, thereafter increasing with advancing age. The youngest patient having osteoarthritis of the hip was 37 years, the oldest 98 years. The osteoarthritis was unilateral in 168 of the 229 patients (56.2 per cent).

Mild osteoarthritis (grades 1 and 2) was equally common in both sexes in the age

range 60–89 ($P < 0.05$). Severe osteoarthritis (grades 3 and 4) was twice as common in females as in males in all ages ($P < 0.001$). Ten patients aged 50 or younger had osteoarthritis. The arthritis in these patients was secondary to genital dislocation and dysplasia of the acetabulum or central protrusion.

Clinical examination 108 patients

Radiological evidence of osteoarthritis of the hip was found in 299 patients. At the time of the follow-up 179 of them were still alive. Another four refused to participate in the study. In a state of senile dementia too few to be able to give any anamnesis. Two patients could not be traced. Thus, we have a series of 108 patients included in the complete follow-up study.

The complete follow-up study included: history taking, physical examination of the hip joints, measurement of height and weight, laboratory tests for antistreptolysin titre, rheumatoid factor, Rose-Waaler, gonococcal test and serum urate. The result of the X-ray examination was not known at the time of the physical examination.

Social status

On the basis of interviews, the patients and their parents were classified into social classes 4–8 (Noordhoek 1969). In men the social class was the same as their fathers' class. Among the women there was a shift towards a lower social status.

As a person's social class is determined at an early age (Svalastoga & Waal 1964) there can be no question of osteoarthritis causing a lower social status, but the shift from a higher to a lower social class might indicate that a low social status increases the risk of osteoarthritis in women.

tion

patients were questioned about the of their work which was divided into grades according to the physical ss (Shepherd 1954, Sneppen 1972) A proportion of the men than of the had heavy work (more than one-third men as compared with less than one-the women) This difference is not int, but the study confirms Kellgren & ce's (1961) assumption that osteo- in men is affected by heavy physical hich increases the prevalence

ular importance was given to whether rents had changed their occupation of the hip disease This was true of ree, all women A lawyer had chosen ry work in the insurance branch, a hairdresser had changed to a sedentary ring job, and a factory worker had l to sedentary instead of standing

litation, disablement pension

patient had tried rehabilitation year-old dustman with osteoarthritis ary to gout), but gave up because of ties in learning and was awarded dis- nt pension

ng the 108 patients, 6 men and 18 were receiving disablement pension : of osteoarthritis of the hip

men and five women had retired early nsion, and two women were receiving lement benefit (which is lower than a ment pension), but were still working ment pension was awarded rather l the men were 56 years or over except e who was 43 The women were 51 or over except for four who were 21, and 46

eight men and two women had gone any form of sport during their lives. : them there was no question of

increased complaints on account of the osteoarthritis — on the contrary The findings do not support Murray's theory (1971) that increased athletic activity during youth is an aetiological factor in osteoarthritis of the hip Puranen et al's (1975) study of 74 contest runners also disproved that sport could contribute to inducing osteoarthritis of the hip

Radiological severity and site of the osteoarthritis

In the 108 surviving patients who attended follow-up there were fewer unilateral cases than in the total material (43/108 *versus* 168/299) Moreover, there was a preponderance of severe osteoarthritis in the group that attended follow-up (36 per cent *versus* 25 per cent) Both findings can be explained by the patients getting older during the period elapsing from the time of the X-ray examination of the colon to the follow-up examination Radiological regression was not observed in any case

Classification of the osteoarthritis according to site in the hip joint (Danielsson 1964, Pearson & Ridell 1962) was based upon an anteroposterior 30 × 40 cm film of both hip joints, 50 per cent were lateral, 24 per cent medial, and 26 per cent mixed Danielsson (1964) found 33 per cent to be lateral, 22 per cent medial, and 45 per cent mixed Pearson & Ridell (1962) 78 per cent lateral and 22 per cent medial In the three series, then, the occurrence of a medial localization was the same (22–24 per cent), but there is a disagreement about the lateral occurrence

On the basis of the X-ray appearances, supplemented by anamnestic data, the aetiology of the osteoarthritis was assessed The frequency of osteoarthritis secondary to dislocation coxitis and trauma does not differ from previous findings Murray's claim (1971), that subclinical epiphysiolysis is often responsible for the occurrence of osteoarthritis of the hip, could not be confirmed

Table 1 History of pain and localization of pain in 108 patients with osteoarthritis of the hip (74 men and 71 women)

	37°	%
Morning stiffness	19	4
Starting pain	21	6
Pain on movement	21	6
Pain during weight bearing	26	9
Rest pain	11	7
Pain disturbing sleep	3	2
Localization		
Anterior aspect of hip	10	1
Posterior aspect of hip	7	1
Lateral aspect of hip	4	
Knee joint	8	1
Knee joint, without signs of knee joint disorder	1	1
No pain	12	8

Clinical evaluation of the pain in osteoarthritis of the hip

The nature of the pain in patients with osteoarthritis of the hip and the site of the pain are listed in Table 1. Twenty-two patients had no pain at all.

Table 2 gives a numerical grading of the pain according to Merle D'Aubigné (1952).

In Table 3 the patients' own assessment of the complaints is summed up. Half of them did not attribute much importance to the osteoarthritis, and one-fifth were entirely symptom-free.

These tables confirm what had already been concluded from the radiographic

findings. In the women the osteoarthritis was more severe than in the men.

Three of the patients who attributed importance to their hip joints had suffered pain. Thus, in three of the patients the osteoarthritis had been

Objective clinical evaluation of the patients

The patients' height and weight were measured. The ideal weight in kg was to be the height in cm less 100 (± 1 kg) (Werner & Berfenslam 1960). 33 per cent were overweight and 24 per cent

Table 2 Evaluation of pain in 108 patients with osteoarthritis of the hip (Merle D'Aubigné 1952)

Points	Pain	♂	%
0	Very severe constant pain	1	1
1	Very severe pain disturbing sleep		
2	Severe pain during walking, all activities restricted	3	3
3	Bearable pain limited activities	3	4
4	Pain only after walking quickly disappearing during rest	7	7
5	Mild pain activities not restricted	9	9
6	No pain	12	12
		37	37

3 The patients' own evaluation of their disability (37 men and 71 women)

	♂	♀	
ility	11	10	54
iscomfort	12	21	
able discomfort	6	21	54
d	8	19	
	37	71	

ight This corresponds to normal navian series

overweight patients were more ed by their osteoarthritis than the un- ight ones, but in accordance with : & Dickson (1968) there was nothing icate that being overweight was an ytical factor in the development of rthritis of the hip

bility in the hip joint was related to the ogical osteoarthritis and to the sub- complaints. In broad terms, there was mity between mobility and radiological ty, yet five patients had good mobility e severe radiological osteoarthritis. On ther hand, none had major limitation of ment in the presence of mild os- rthritis. The complaints increased with ed mobility, but the most serious com- s were caused by articular contractures o-thirds of the patients had clinically ptable shortening of one leg

If the patients with osteoarthritis of the ad associated venous insufficiency. This ce the prevalence found in the adult sh population (Arnoldi 1958, Borschberg

it was normal in 19 patients none of a was bothered by their osteoarthritis of up, although radiologically it was con- able in six. In the remaining patients the attern was characterized by a leaning of body towards the osteoarthritic joint. hird of the patients walked without a

stick, and one-quarter used one ordinary stick (Table 4)

The patients' ability to manage simple everyday tasks, such as putting on shoes and socks and walking stairs was evaluated and it was found that the women were less able to cope than the men

Treatment

It was mainly pain which made the patients consult a doctor, and to a lesser extent difficulty in walking or working

Thirty out of the 108 patients had never sought medical treatment for their osteoarthritis of the hip, their complaints not being so severe that they could not manage without treatment. Only a few had consulted a chiropractor or a natural healer, and only one patient had exclusively received that kind of treatment (acupuncture). Two patients had been rejected by a chiropractor who could not do anything about their arthritis.

The treated patients had received medication and physiotherapy, only eight had undergone surgery. Eleven patients had been treated by X rays

Table 5 sums up the data for the eight operated patients. Only five had undergone operations which are still in use today. The operated group is too small to permit any evaluation of the result

Table 4 The use of a stick and crutches among 108 patients with osteoarthritis of the hip

	No walking aids	Using 1 stick	Using 2 sticks	Using 1 elbow-stick	Using 2 elbow-sticks	Using a walking frame	Unable to walk	Total
♂	17	11	2	3	1	2	1	37
♀	20	16	5	3	10	15	2	71
Total	37	27	7	6	11	17	3	108

Table 5 Surgery among 108 patients with osteoarthritis of the hip (Eight patients had surgery performed)

Patient No.	Sex	Age in years at surgery	Duration of osteoarthritis at surgery, years	Follow-up period, years	Radiological degree of osteoarthritis Right/left	Type of operation	Indication for surgery	Patient's own evaluation of the effect of surgery
14	♂	71	5	5	1/4	McKee-Farrar	Pain, difficulty in walking	Some effect
18	♀	58	9	31	4/4	Adductor tenotomy	Pain, difficulty in walking, difficulty in working	No effect
37	♀	64	10	5	4/4	McKee-Farrar, bilateral	Pain, difficulty in walking, bilateral ankylosis	Some effect The patient is in a wheelchair
49	♀	66	6	3	3/4	Intertrochanteric osteotomy, right	Pain, difficulty in walking, difficulty in working	No effect
67	♀	69	17	1	3/1	Intertrochanteric osteotomy, right	Pain, difficulty in walking	Good effect
76	♀	85	5	1	0/4	Resection of obturator nerve	Pain	Good effect
107	f	60	1	3	4/4	McKee-Farrar left	Pain, difficulty in walking	Good effect
111		57	14	27	4/4	McKee-Farrar right	Pain, difficulty in walking	Good effect

men and seven women in the present were advised by the author to have an operation. The aim of surgery is primarily to relieve the patients of pain, and secondarily to increase their mobility in some of the hips. Indication for surgery in this series was that the advice was given only to patients with pain on weight-bearing as well as rest, disturbing their sleep. All these patients had radiological grade 3 or 4 osteoarthritis (Jensen 1963), and the operation was performed only after a duration of several years. Males and three females disabled by their disease were so debilitated by old age that it was considered wise to offer them any kind of surgery.

Our patients (out of 108) having radiological evidence of osteoarthritis of the hip without major complaints

In these cases 44 per cent were medial (or medial) as compared with only 24 per cent among the total of 108. This confirms Jönsson's (1970) finding that medial osteoarthritis has a more favourable prognosis than lateral (in the sense that it bothers the patient less).

Mobility in the hip joints was better in the patients without major complaints, and they had fewer contractures. There was no difference between these patients having been spared surgery and those who had been operated on, on the contrary.

CONCLUSION AND SUMMARY

Of 6321 patients who had undergone X-ray examination of the hip, 4.7 per cent were found to have osteoarthritis of the hip. The male to female ratio was 3:2, and in both sexes the prevalence rose with advancing age. Mild osteoarthritis was equally common in both sexes, but in all age groups above 60 severe osteoarthritis of the hip was twice as common in men as in women. In the total of 108 patients (37 men and 71 women) attended clinical follow-up examination

Osteoarthritis setting in at an early age (at 50 or earlier) was found to be secondary. In 50 per cent the arthritis was located laterally and in 24 per cent medially. The medial cases had a more favourable prognosis (the arthritis was less troublesome) than the lateral ones.

A low social status increased the prevalence of osteoarthritis of the hip in women (but not in men), and heavy physical work increased the frequency in men. There was no evidence that participation in sport might increase the risk of osteoarthritis affecting the hip joints.

During the years which had elapsed from the X-ray examination of the hip to the time of the follow-up, the osteoarthritis had progressed. Only in three of the 108 patients had the osteoarthritis "burnt out".

The main complaint was pain, usually affecting the anterior side of the hip. Patients without pain did not know they had osteoarthritis of the hip, or else they did not pay any attention to it. One-third of the men and almost half the women had rest pain. One-fifth of the patients were free of pain, and one-quarter had never sought medical advice because of their hip disease. One-half had no complaints or only mild ones.

There was not a greater number of overweight patients among those with osteoarthritis of the hip, but overweight patients were more troubled by their osteoarthritis than others.

Contracture of the hip was more annoying than restricted mobility and half the patients had venous insufficiency (which is twice the prevalence in the general adult Danish population).

In keeping with the fact that the osteoarthritis was more severe radiologically in the women than in the men, the women were also more severely affected by the condition. They more often had to apply for disablement pension, they had more severe pain, and they were more handicapped in activities of daily living.

Thirty-three out of 108 patients were so debilitated by their hip disease that they had been awarded disablement pension, others

received disablement benefit, or early old-age pension

According to the present study, only half the patients who exhibit radiological evidence of osteoarthritis of the hip actually need treatment. Among those who do, it is estimated that one-third would benefit from surgery, chiefly total alloplasty

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PERIPHERAL AND SCIATIC NEUROPATHIES AFTER TOTAL HIP ARTHROPLASTY

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Six patients with peripheral nerve lesions after total hip replacements were reviewed. The incidence of peripheral nerve lesions was six out of 825, i.e. 0.7 per cent. The neuropathies, four sciatic, one femoral and one combined femoral and sciatic, were due to damage by the reamer in one case, haemorrhage in two, whereas the cause was unknown in three patients. After conservative treatment and 1-5 years follow up the recovery was classified as good in three, fair in one and poor in two patients.

Key words: femoral and sciatic nerve injury, peripheral nerve lesion, total hip arthroplasty.

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Peripheral neuropathies are an uncommon but troublesome complication of total hip arthroplasty. The incidence of clinical peripheral nerve damage varies from 0.53 per cent (1976) to 3 per cent (Evarts et al 1976). Buchholz & Noack (1973) reported a 1.52 per cent and permanent nerve damage in 0.41 per cent. This report presents six patients with complications, emphasizing the causes, treatment and prognosis.

Christiansen's trunnion bearing prosthesis with varying neck sizes of 5, 10 or 15 mm was implanted to obtain a correct length of the extremity and to avoid undue tension in the soft tissues and neurovascular structures after reduction.

All six patients had a prolonged convalescence after the arthroplasty, the hospitalization period being 7-10 weeks.

All the complications were treated conservatively with exercises, crutches, electrical stimulation and orthotic devices.

Case reports

Case 1 In a 77-year-old woman with necrosis after a fracture of the right femoral neck the sciatic nerve was pulled by the reamer through a posterior hole in the acetabulum. The nerve was judged to be macroscopically intact by inspection. Postoperatively there was complete paralysis of the extensor and peroneal muscles of the foot, weakness of the biceps femoris muscle and loss of sensation over the dorsum of the foot and the lateral aspect of the calf. Five years after the arthroplasty the patient was still using a toe strap for her drop foot and the condition was unchanged. The recovery was classified as poor (Table 1).

RESULTS AND METHODS

During a period of 8½ years, from September 1970 to May 1979, a total of 825 total hip arthroplasties were performed and clinically evident neuropathies developed after the operation in six patients, i.e. there was an incidence of 0.7 per cent. The posterior approach was used in all patients with nerve lesions (out of the 825 operations) and none of them had reoperations or complications by posterior dislocation. Fifty-four per cent of the total number of operations were on women.

Most likely this heavy traction injury caused an undiscovered partial rupture (neurotmesis) of the nerve.

Case 2 A 62-year-old woman with osteoarthritis of the right hip presented postoperatively a peroneal nerve palsy with dropfoot. However, definite weakness of the hamstrings aroused suspicion of a more proximal lesion. The electromyographic examination revealed a denervation pattern of the hamstrings and the extensor and peroneal muscles of the foot and substantiated the diagnosis of a sciatic nerve lesion. Within 2 months postoperatively there was some return of function of the hamstrings. Two years after the operation the patient had completely regained function, both clinically and electromyographically and the result was classified as good.

The cause of the nerve lesion in this case was unknown, presumably, the nerve was stretched or injured by retractors.

Case 3 A 68-year-old woman with an arteriosclerotic disease, treated with arterial reconstructive surgery in the right thigh, was 5 years later operated upon for osteoarthritis of the right hip. After the operation there was complete peroneal nerve paralysis, weakness of the tibial nerve innervated flexor group and loss of sensation over the entire foot and the lateral aspect of the calf. During the following months she regained full function of the flexor muscles. After 1 year there was also some return of function of the extensor muscles but she still used a toestrapp when walking outside. The result was rated as fair.

The cause of the nerve injury was unknown, but stretching of the nerve or injudicious retraction during the operation, in addition to the impaired circulation of the extremity, might well have contributed to the sciatic nerve palsy.

Case 4 A 58-year-old woman with an osteoarthritis of the left hip revealed postoperatively a total paralysis of the left quadriceps muscle and hypoaesthesia in the whole distribution of the femoral nerve. Electromyographic and nerve conduction examinations showed complete denervation of the quadriceps muscle and also mild sciatic

was probably due to stretching or retraction of the nerves.

Case 5 A 64-year-old man with coxarthrosis of the left hip suddenly experienced pain in the left thigh on the sixth postoperative day. The following day the thigh became tender and the function of the ankle and foot and of the peroneal muscles was completely lost. The Achilles reflex was absent but the knee reflex, however, proved to be normal. Over a 3-year period, using a dorsiflexion brace for his foot, there was no improvement of the nerve function and the recovery was classified as poor.

The cause of the sciatic neuropathy was a haemorrhage and haematoma due to postoperative warfarin (Marevan®) anticoagulant therapy was adequately adjusted (TT ≥ 7 per cent).

Case 6 A 63-year-old woman, operated upon for rheumatoid arthritis of the left hip, experienced pain in the left groin 4 weeks postoperatively. During the following day the pain increased and radiated down to the knee and leg. It appeared on the medial aspect of the left thigh and the groin. She developed a complete paralysis with loss of sensation in the patellar reflex and loss of sensation in the medial and lower aspect of the thigh, extending to the inner side of the leg. The electromyographic and nerve conduction examinations showed complete denervation of the quadriceps muscle. During the following 6 weeks the patient noticed some return of function of the quadriceps muscle. After 1 year there was complete recovery, only the sensory function of the medial part of the lower leg was still impaired. The recovery was classified as good.

This case demonstrates a typical femoral neuropathy with femoral nerve palsy and haematoma. The neuropathy was caused by haemorrhage during extension exercises of the hip during postoperative warfarin anticoagulation. Although the anticoagulant therapy, also in this case, was adequately adjusted (TT ≥ 7 per cent).

RESULTS

After a follow-up period of 1-6 years, the recovery was classified as follows: 10 patients represented complete recovery, 10 patients represented partial recovery with decreased function, and 10 patients represented no improvement of function.

After a follow-up period of 1-6 years, the recovery was classified as follows: 10 patients represented complete recovery, 10 patients represented partial recovery with decreased function, and 10 patients represented no improvement of function.

The cause of the nerve injury was unknown, but

1 Clinical data in six patients with peripheral nerve injuries after total hip arthroplasty

Sex	Age	Type of neuropathy	Cause	Recovery at follow up (years)	
♀	77	Sciatic	Reamer	Poor	5
♀	62	Sciatic	Unknown	Good	2
♀	68	Sciatic	Unknown	Fair	1
♀	58	Femoral, sciatic	Unknown	Good	1
♂	64	Sciatic	Haemorrhage	Poor	2
♀	63	Femoral	Iliacus haematoma	Good	1

e Three patients were classified as one as fair and two as poor (Table 1)

DISCUSSION

operative trauma with traction and ulation during hip surgery may render rves more vulnerable. In a prospective with EMG before and after plasty through a lateral approach, et al (1976) found that subclinical damage occurred in 70 per cent of the ts, and often more than one of the ; femoral and obturator nerves were ed

ve palsy may occur because of ung, retraction or direct impingement ie nerves (Murray 1973) after local re from cement or damage caused by at of the polymerization (Moczynski et 1973) but it may also be caused by perative hip dislocation (Lazansky

tic nerve palsy due to intra and/or ex- al haemorrhage has been described in ts receiving anticoagulants (Fleming et 79) Iliacus haematoma complicated by al nerve palsy, secondary to haemophilia (fellow et al. 1967) therapeutic or pro- tic heparin (Stern & Spiegel 1975) or rin anticoagulation (Brantigan et al is well known but has also been ed after trauma (Green 1972)

mediate decompression of the nerves intra- and/or extraneural haemorrhage is imended if the palsy is progressing and ight have led to a better outcome in

Case 5 in our material. In contrast, Case 6 with an iliacus haematoma demonstrates, like most of the reports from the literature the good results of conservative treatment for this condition

On the whole, the treatment of nerve injuries due to operative trauma or fracture is often conservative if the nerves are thought to be macroscopically intact. Explorative surgery is recommended 7-8 weeks after nerve damage if there are no signs of nerve regeneration (Hagen 1970). Any strong suspicion of direct lesion or impingement on the nerve by cement, bone or sutures, with no sign of recovery, should probably be explored even earlier.

However, none of these possible causes was suspected among our cases. Neither was there any apparent correlation between nerve damage and the lengthening of the extremity produced by the arthroplasty which amounted to $\frac{1}{2}$ -1 cm in five patients and 2 cm in one patient.

Case 2 demonstrated a clinical finding which was also pointed out by Weber et al. (1976) that an apparent peroneal nerve palsy is more likely a result of sciatic nerve damage at the level of the arthroplasty. A thorough clinical and electromyographical examination may verify the level of the nerve lesion in doubtful cases.

There was a preponderance of women in our material. We are of the opinion that this female predisposition might be due to an increased vulnerability of the nerves because of a changed vascular supply after pregnancy and not to their having less muscle bulk as suggested by Weber et al. (1976).

The material indicates that the prognosis for most of the patients with severe nerve injuries after total hip arthroplasty is good unless the nerve has been badly damaged, as in our Case I.

Peripheral nerve injuries, i.e. those with clinical evidence of nerve damage, in connection with hip arthroplasty can be avoided if careful surgery is performed. This study has not provided evidence against the use of the posterior approach which in our opinion has several advantages.

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STABILITY OF THE ACETABULAR SOCKET AFTER TOTAL HIP REPLACEMENT DETERMINED BY ROENTGEN STEREOPHOTOGRAMMETRY

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In order to evaluate the feasibility of a roentgen stereophotogrammetric method for the analysis of the migration pattern of joint prostheses, tantalum balls were implanted into the acetabular socket and the pelvic bone during total hip replacement in four patients with rheumatoid arthritis. During the postoperative period the migration of the acetabular socket was determined. The observation period varied from 5-24 months.

No clinical or radiographic signs of mechanical loosening or infection were noted.

All the investigated patients showed a gradual migration of the acetabular socket. The cranial migration measured up to 1.8 mm in 2 years. The migration along the transverse and sagittal axes was less but not constantly directed. The rotatory movements about the three axes varied and measured up to 5.5° in 2 years. The translation and rotation were greatest during the first few months.

The results indicate a gradual migration of the acetabular socket in hip arthroplasty in the osteopenic skeleton in rheumatoid arthritis.

In conclusion roentgen stereophotogrammetry may prove to be a valuable means of analysing the migration of implanted prostheses and detecting prosthetic loosening, thereby increasing the possibility of early and correct diagnosis and therapy.

Key words: arthroplasty, hip, knee, prosthesis, rheumatoid arthritis, roentgen stereophotogrammetry

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In most cases of total hip arthroplasty, there are no signs of mechanical loosening or migration (Charnley & Cupic 1973). On the other hand, it is not a completely stable operation, but one maintained by a fibrous capsule which develops between the bone and the prosthesis and the bone cement (Willert et al 1974). It has been shown that a total hip prosthesis is unstable because of infection or

mechanical causes, can be exchanged with good results (Lundberg et al 1977). To ensure the best possible conditions at the exchange operation, any instability of the prosthesis must be detected at an early stage before too much bone around the femoral and acetabular prosthesis and the bone cement has been resorbed.

The conventional radiographic examination of total hip prostheses often provides too

Table 1 Movement of the acetabular socket in relation to the pelvis. Positive translations from the origin along the X, Y and Z axes are defined as, to the left side, in the cranial direction and in the anterior direction of the patient, respectively. Translations are given for the geometric centre of the acetabular tantalum indicators or for the medial (m) and lateral (l) tips of the acetabular wire of the Charnley-type prosthesis (Case GL). Rotations of the acetabular socket with tantalum indicators are defined as positive in the clockwise direction about different axes (as viewed from the origin)

Case	Sex	Age at operation	Type of hip prosthesis	Observation period in days after first examination	Rotary movement in degrees about			Translatory movement in mm along		
					transverse axis	longitudinal axis	sagittal axis	transverse axis	longitudinal axis	sagittal axis
					X	Y	Z	X	Y	Z
GA	M	69	Right Brunswik	0-33	-0.8	0.4	-0.4	-0.32	0.00	-0.53
				0-166	-0.1	0.2	-1.3	-0.23	0.13	-0.22
				0-404	-0.8	0.2	-1.5	-0.35	0.42	-0.15
BJ	M	38	Right Charnley	0-89	-1.0	0.1	2.9	0.40	0.97	-0.08
				0-196	-2.1	0.4	3.5	0.18	1.20	0.23
				0-376	-1.3	0.7	4.3	0.15	1.46	0.39
				0-741	-1.4	0.5	5.5	0.06	1.75	0.06
SH	F	55	Right Charnley	196-376 ⁽¹⁾	0.4	0.4	-0.2	-0.33	0.15	0.07
				196-741	0.1	0.3	-0.1	-0.40	0.19	0.36
GL	M	53	Left Charnley	0-140				-0.31 ^m	0.49 ^m	-0.51 ^m
								0.04 ^l	0.21 ^l	-0.29 ^l

¹⁾ The first two postoperative examinations could not be used since one of the three implanted balls in the pelvic bone was found to be unstable. A fourth tantalum ball was then inserted and found to be stable.

little information about loosening (Sjostrand 1974). In particular the acetabular socket in total hip prostheses is difficult to investigate because of the small differences in projection. There is a need for a precise technique in order to discover prosthetic loosening and migration at an early stage. Therefore tantalum balls were implanted in the socket of total hip prostheses and in the surrounding pelvic bone, and a roentgen stereophotogrammetric method (Selvik 1974) was used to analyse the migration of the acetabular socket in relation to the pelvic bone.

PATIENTS

Four patients with severe disabling rheumatoid arthritis with multiple joint involvement were chosen for this study (Table 1) because there is a high frequency of migration of the prosthesis after total hip replacement in cases of this type. The age of the patients varied from 38 to 69 years. The duration of rheumatoid arthritis varied from 9 to 24 years.

METHOD

The primary objective of roentgen stereophotogrammetry is to determine the three-dimensional co-ordinates of structures in the body (Selvik 1974, Olsson 1975, Olsson et al 1976, Hansson et al 1978). Generally there are no sufficiently distinct points in the body to allow a highly accurate identification in the two projections necessary for a three-dimensional reconstruction.

Therefore 3-5 tantalum balls (Figure 1) diameter 1.0 mm, served as radiopaque indicators, and were inserted into drill holes in the polyethylene acetabular socket of the hip prostheses in three cases. The holes were about 2 mm deep made with a drill of 1 mm diameter. In the fourth case equipment failure prevented the

Figure 1 AP radiographs of the pelvis of patient B: a Preoperative radiograph b Postoperative radiograph showing the tantalum indicators in the anterior and posterior superior iliac spines and the pubic tubercle. Five indicators in the acetabular socket are also seen. c Radiograph at follow-up 2 years after operation

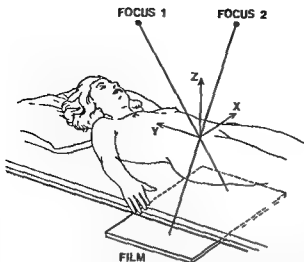


Figure 2 The stereo investigation of a patient. The distance between the foci is about 650 mm, the film-focus distance is about 1200 mm, and the film size is 600 × 400 mm. The directions of the co-ordinate axes are also shown.

insertion of the balls, instead, the ends of the wire in the socket were used as measurement points. Another 3–4 tantalum balls (Figure 1), diameter 0.8 mm, were inserted into the pelvis according to the technique of Aronson et al (1974). They were widely separated in the pelvic bone to increase the precision of the method. Thus they were placed in the anterior and posterior superior iliac spines, the pubic tubercle, and the ischial tuberosity. The tantalum balls serve as measurement points on the radiographs (Figure 1). All the tantalum balls were inserted during total hip replacement.

The radiographic examination (Selvik 1974, Hansson et al 1978) was performed 5–15 days postoperatively and was repeated during the following months (Table 1). Simultaneous exposures of the pelvis with two roentgen tubes on one film were made with the patient supine (Figure 2). On each film, a calibration cage supplied with tantalum indicators, whose mutual positions were known, was also double-exposed. The co-ordinates of the images of both patient and calibration indicators were then measured by means of an instrument for cartography. The information thus obtained was treated by computer so that the three-dimensional positions of the indicators were determined in a laboratory co-ordinate system. This system is defined by the calibration cage markers situated in two planes. The patient is investigated in such a position that the main axes of the body (transverse, longitudinal, and sagittal axes) are parallel to those of the cage co-ordinate system (Olsson et al 1976). In the subsequent analysis, the rigid

body motion between the prosthesis and the pelvis was computed. Translational and rotational movements of the prosthesis acetabulum were calculated.

The precision of the roentgenographic method was estimated to be approximately 0.2° for rotations about and 0.1 mm for translations along the three co-ordinate axes (Olsson 1976).

RESULTS

The tantalum balls in the specific series were in the pelvic bone or in the prosthesis socket, were found to be stable with respect to the acetabular socket and the pelvis behaved as rigid bodies.

In one patient (BJ), the movement of the acetabular socket in relation to the pelvic bone was investigated twice on the same day in the supine position, but there was no significant difference between the measurements. By re-evaluating two roentgenograms (one from patient BJ and one from patient SH) and recalculating the positions of the markers, the rotations were found to differ less than 0.2° and translations less than 0.05 mm, in accordance with the precision tests mentioned above.

In all cases, a migration of the acetabular socket was found but the direction and amount varied (Table 1). In general, there was a gradual migration in the transverse plane. In cases GA, BJ and SH, measurements were made at various intervals over a period of 13–24 months. In one case (BJ) the migration was greater during the first 6 months and amounted to about 1 mm. In the following 21 months, the migration amounted to about 0.8 mm. The movement was along the transverse and sagittal axes but varied considerably in direction in different cases and during the different observation periods. In the same case, in two cases, these movements amounted to less than 0.6 mm during the entire observation period.

The rotatory movements varied considerably in the different cases and during the observation period to another. The trans-

and the direction varied irregularly in the case during the different observation periods. In case BJ the rotation about the vertical axis amounted to 2.9° during the 18 months, the upper part going to the side of the patient. This period was followed by lower rotational values during the next 18 months, the total rotation about the axis amounting to 5.5° in 24 months.

GL, there was a rotatory movement of the socket, judging from the values of the roentgen movements, but this rotation could not be quantitated because there were no measuring points in the socket. During the follow-up, the present cases showed no clinical or radiographical signs of loosening or mechanical loosening. The control radiographs showed no signs of migration of the femoral or acetabular parts of the prosthesis (Figure 1). Clinically, the replaced hip joints did not cause any problems, but the other joints did because of rheumatoid arthritis. Two of the patients (cases GA and GB) died of causes unrelated to the hip replacement 1 and 2 years after operation, respectively. Unfortunately, the hip joints were not examined at the autopsies.

DISCUSSION

Of the investigated patients with rheumatoid arthritis had symptoms of prosthetic loosening during the observation period of at most 24 months. No migration of the sockets could be detected on conventional radiographs taken at the same time as the roentgen stereophotogrammetric examinations.

In this investigation, a continuous migration of the acetabular socket measuring 1.8 mm in 11 years was found along the vertical axis in the cranial direction. A similar migration was also found along the horizontal axes, but the directions varied even in individual cases during the different observation periods. The same was also found concerning rotatory movements. In total, the translatory and rotatory

movements were greater during the first few months after the operation than later on.

The investigated cases showed no indication of a completely stable prosthesis, instead, there was a continuous migration upwards with a translation and rotation along and about the different axes varying both in amount and direction. A similar migration of a knee prosthesis (Marmor) in a woman with rheumatoid arthritis has been found for the polyethylene tibial plateau resulting in tilting of the tibial prosthesis.

The roentgen stereophotogrammetric method is applicable to all non-radiopaque plastic prostheses. With modifications, it can be used for metal prostheses. Indicators should be inserted into the prostheses during manufacture but can be inserted during the operation. In some cases, for instance, with the Charnley hip socket, the method can be of use without special indicators in the prosthesis, the ends of the wire being used as indicators.

In conclusion the roentgen stereophotogrammetric method can be a valuable aid in the early detection of prosthetic loosening, thereby increasing the possibility of obtaining a correct diagnosis and instituting appropriate therapy.

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FUNCTION AFTER REMOVAL OF A SEPTIC TOTAL PROSTHESIS

Survey of 27 Girdlestone Hips

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An evaluation of the results of removal of a septic total hip prosthesis in 27 patients was made at least 1 year after the operation. The function of many of the patients improved throughout the first year after removal. It is concluded that the Girdlestone hip in many cases offers a satisfactory solution for the patient.

Key words: function, psychiatric and social evaluation, septic total hip prosthesis, removal

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Removal of a total arthroplasty of the hip is an extremely distressing experience for a patient. A two-stage procedure including removal of the infected prosthesis and immediate insertion of a new one may succeed in certain cases (Lindberg et al 1977). In some cases, however, such a procedure is not possible and the only way is to remove the prosthesis. In order to evaluate function following simple removal we decided to review 27 patients at least 1 year after extraction of the prosthesis. The survey is based on a clinical and radiographic examination and also includes a social and psychological assessment.

RESULTS AND METHODS

Twenty-seven patients, 15 males and 12 females, were available for review 1 year or more after removal of their septic total hip prosthesis. Twenty-five were of the Charnley type and one of the McKee-Farrar type. The mean age at arthroplasty was 63.6 years (range 41 and 81) and at review 67.5 years. The average

interval between extraction and the review was 40.6 months (range 12-68 months).

Twenty-two of the patients had been operated upon for primary coxarthrosis, three for complications following fracture of the femoral neck, one for rheumatoid arthritis and one for secondary changes after congenital dislocation of the hip.

Sixteen of the patients with arthrosis had a bilateral affection. Of these six had been also treated with arthroplasty of the other hip. Except for the fractures none of the hips in question had been operated upon previously.

In the interval between arthroplasty and extraction of the prosthesis the wires holding the greater trochanter had been removed in three cases and extraction-reimplantation had been attempted in two.

The psychological and social evaluation was performed jointly by a psychiatrist, a social worker and an occupational therapist, all of whom had no previous knowledge of the patients and worked independently of the Orthopaedic Department.

Pain on weight-bearing, raised erythrocyte sedimentation rate and radiographic signs of loosening were constant findings in all 27 cases.

Pain was the prominent symptom in all but three cases. In these, removal was indicated by a profuse and persistent secretion from a sinus.

Table 1 Age at arthroplasty

Years	
40-49	2
50-59	8
60-69	9
70-79	8
Total	27

Table 2 Walking ability

-2 km	1
-0.5 km	1
-200 m	1
Indoors only	1
Mainly confined to a wheelchair	1
Total	5

Local inflammatory signs occurred at one time or another in all cases, in 15 with fistulation. In 14 of these cases bacterial cultures were positive.

Before extraction of the prosthesis the patients had received a fairly long course of antibiotic therapy. This treatment had resulted in abatement of symptoms of varying duration. Routine culture of specimens obtained at extraction was positive in 15 cases.

Postoperatively skeletal traction was applied for 4 to 5 weeks, followed by training in a walker with full weight-bearing. A shoe raise, usually of the order of 5 cm, was always necessary.

At operation we tried to remove all the cement. Such removal, particularly from the femur, was often a very arduous task even though access was facilitated by fenestration or guttering of the shaft and/or chiselling off of the greater trochanter. In 12 cases some fragments of cement were left behind, but this did not seem to interfere with wound healing except possibly in one of the patients who had a recurrent sinus secretion for up to 1 year after the removal.

In 19 cases healing was by first intention. In the remaining eight cases healing was delayed: three had a secreting sinus for up to 3 months and five had persistent or recurrent drainage for longer periods and one for as long as 16 months. Antibiotic therapy was generally discontinued 3 months after all signs of infection had disappeared. In no case was a second operation performed to remove remaining cement.

RESULTS

Subjective evaluation

All of the patients were satisfied with the overall result of the operation and some felt that the outcome greatly exceeded their expectations. Freedom from pain and soiling drainage was particularly appreciated.

All of the patients reported that the hip

was much better and much less painful than it was before both insertion and removal.

Eighteen patients had no pain at all, nine only had mild or occasional pain in association with changes in the weather after much walking or standing.

Pain on weight-bearing was reported by seven patients, this was slight or moderate in five and more severe in the remaining two. Three of these seven were not satisfied with the pain-relief obtained and the loss of function and later underwent a second arthroplasty.

The ability to walk varied considerably with the general health and status of the patient (Table 2). Thus 22 could walk outdoors alone, whereas five needed help from another person. Of these five, four were mostly confined to a wheelchair. It should be pointed out that the hip was not responsible for the incapacity of the patients who suffered from gait instability or stiffness of other joints, vertigo and senility.

Walking aids were used to some extent by all patients able to walk, mostly for outdoors and one indoors. All three felt that their gait and the distance they could walk gradually improved during the first 6 months. Many of them had been troubled by a feeling of instability and a marked tendency to stumble. Several of these could not move safely around the house after the operation.

All but one patient found the free motion of the hip was sufficient for comfortable sitting. One patient had a restricted motion of both hips and most of his time in a wheelchair.

motion was invariably very limited initially, but gradually improved with muscle tone during the first few

Medical and social evaluation

Purpose of this aspect of the follow-up was to evaluate the patient's subjective response by assessment of his degree of mobility and anxiety, disturbance of sleep, need for tranquilizers, and also an assessment of his ability, working capacity and social activity. Finally, the patients were interviewed personally concerning their response to the hospital care and the aids they had used to relieve their handicap. Most of the patients regretted the extracapsular prosthesis, but one did regret the operation. Broadly speaking, the patients were satisfied with the results of the operation. The main reasons for this were the relief from severe pain, the disappearance of the embarrassing fistula.

Only four of the patients had no difficulty in eating, dressing or managing personal hygiene. Twelve of the patients were living alone and two were living in a home. All of those living alone received help with the heavier chores and the washing, but most of the women nevertheless found the household strenuous. The men living alone required help with the cooking and

Those who earlier had been able to drive could still do so. However, most of them had their cars exchanged for those with automatic gears. All of the patients except one stated that they could continue with their activities and hobbies to the same extent as before.

Three of the patients reported psychological symptoms but all of them had earlier suffered from depression, anxiety and disturbance of sleep and all needed tranquilizers. Another three patients required assistance. Two patients had part-time jobs and one was working full time as before. The others were pensioners.

All of the patients except one were satisfied with the care and treatment they had received, including the special aids supplied to help relieve their handicap. The patient who was not satisfied thought that the infection was due to a mistake made at the earlier operation.

Clinical evaluation

All of the patients could stand and even the two most severely incapacitated could take a few steps with the aid of a walker. All had a positive Trendelenburg sign. Gait was rated as good in 19 cases, fair in four and poor in four.

Shortening varied from 3 to 8 cm, most frequently from 4 to 5 cm. Radiograms on weight-bearing demonstrated that the shortening increased by 5 cm in one case, by 2 cm in 19 cases and by 1 cm in seven cases.

In the supine position all except one of the patients had an active flexion range of 50 degrees or more. Passively flexion could be increased by 20–30 degrees (Table 3). Active rotation and range of abduction and adduction was reduced in most cases but could be increased passively, especially outward rotation and adduction. Four patients had flexion contractures of 15 to 30 degrees and six had contractures in outward rotation of the order of 10 to 30 degrees. No adduction contractures were encountered and no relationship was found between the presence of contractures and walking capacity.

DISCUSSION

Santesson (1849) reports that Charles White of Manchester suggested in 1770 the

Table 3 Range of flexion

	Active	Passive
0–30°	1	0
31°–60°	8	4
61°–90°	18	10
91°–120°	0	13
Total	27	27

resection of the femoral head as a measure against tuberculosis. However, Anthony White was the first one to make the operation in an infected case. According to Santesson (1849) the operation was performed in 1818 at Westminster Hospital in London. Girdlestone (1943, 1945) used this procedure not only in the treatment of tuberculosis and pyogenic arthritis of the hip but also in osteoarthritis. The operation now bears his name and is most certainly very seldom used as a primary treatment but is regarded as a salvage procedure, for example, in primary infections, avascular necrosis and in cases where the general condition of the patient precludes more extensive surgical interventions (Murray et al 1964, Collis & Johnston 1971, Parr et al 1971).

The operation has also long been used in the case of failed hip arthroplasty and in recent years it has received renewed attention as an ultimate measure after unsuccessful total hip arthroplasty (Plaue & Stadler 1975, Haw & Gray 1976, Slooff et al 1976, Vidal et al 1977, Clegg 1977, Gudmundsson et al 1977). In general these authors have found the result good or acceptable but have not excluded the possibility of another arthroplasty.

Josefsson et al (1978) have compared the functional results of the Girdlestone procedure to those of exchange arthroplasty. Admittedly the latter gives a better result but the difference was less than expected.

The result of earlier investigations and the present one has led us to conclude that a septic total hip arthroplasty should first be treated by the Girdlestone procedure, which should not be delayed too long once infection is diagnosed. Assessment of the result should be delayed for several months and if the outcome then is unsatisfactory for the patient, arthroplasty should be performed provided it is technically possible. This strategy is in accordance with that of Slooff et al (1976) and Vidal et al (1977) but contrasts with that of Lindberg et al (1977).

We have not found complete removal of the cement an absolute necessity for healing

which is in contrast to Clegg's (1977).

The optimal period of traction does not yet seem to be established. Haw & Gray (1976) advised skeletal traction for 6 weeks. Lindberg et al (1977) used traction for periods less than a week to 2 months. The correlation between the length of time the patient was held in traction and the shortening or function. The time of present investigation, 4-6 weeks, seems reasonable to us and during this time the patient was allowed intermittent mobilization of the hip and knee.

The opinions of the patients expressed by the orthopaedic surgeons all followed the same pattern. It was surprising how well the patients understood the stress connected with an unsuccessful arthroplasty and also that only a few had a grudge against the medical profession.

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POPLITEAL CYSTS (BAKER'S CYSTS) IN ADULTS

capsuloplasty With and Without a Pedicle Graft

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In 15 adult patients undergoing surgery for symptomatic popliteal cysts of fairly long duration the communication into the joint was closed by two different procedures. In the early series *Series A* (8 patients) the opening was tightly sutured and in *Series B* (7 patients) a new type of capsuloplasty was performed using a proximally based flap from the gas-

whereas radical excision of the cyst does not seem essential for the therapeutic result

Key words: popliteal cysts Baker's cysts capsuloplasty

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al cysts are still considered today by authors to be due to a synovial hernia through the capsule of the knee joint (Berman 1972, Pinder 1973, Ler & Kirkpatrick 1975). The prevailing opinion is however, that they are fluid-filled communicating gastrocnemio-sembranosus bursae (Gristina & Wilson 1964, Goldstein & Dickerson 1974, Smilie & Lindgren 1978, Rauschning 1979). These cysts are often caused by an underlying intra-articular disorder (Burleson et al 1966, Gristina & Wilson 1964, Bowerman & Hietaler 1973) and a correction of the disease constitutes rational treatment in most cases (Jayson et al 1972, Pinder 1973). An associated knee disorder is not curable if the cyst gives rise to troublesome

symptoms, it is the general opinion that surgical excision is the treatment of choice (Justis 1971, Smilie 1974). Most authors also advocate closure of the communication (Haggart 1943, Childress 1970, Solomon & Berman 1972).

Recurrences following conventional surgical treatment are frequent (Harvey & Corcos 1960, Vahvanen 1973, Meire et al 1974). In a recent clinical and radiographic follow-up examination of 41 routinely excised popliteal cysts, 15 postoperative complications and 40 recurrences were found (Rauschning & Lindgren 1979).

This paper describes a modified surgical approach and operative technique. In an earlier series (*Series A*), the cyst was tightly sutured, and in *Series B* a

developed reinforcement capsuloplasty was applied, with the use of a pedicle graft from the gastrocnemius tendon

PATIENTS AND METHODS

Patients, preoperative symptoms and findings (Tables 1 and 2)

During the period June 1975 through May 1977, 15 adults, aged 19–69 years (mean age 42.7 years) were operated upon consecutively by the author for popliteal cysts at the Department of Orthopaedic Surgery, University Hospital, Uppsala. Six cysts presented in the left knee and nine in the right. Nine of the male patients recalled a specific knee injury, in most cases

sustained during sports. The duration of symptoms averaged 5.6 years (range 1–17 years). They were assessed according to the following clinical criteria: Grade 0 no pain, Grade 1, swelling and slight tenderness after strenuous work or sports, Grade 2, tenderness after normal activities, Grade 3, constant tense swelling and pain.

Associated disorders of the knee were noted among these patients (Tables 1 and 2); in a few cases was surgical treatment of the existing condition considered indicated.

At preoperative arthrography all cysts were identified as communications of the posterior semimembranosus bursa on the basis of a lack of communication and the appearance of the tendons behind the knee (Fig. 1). At admission to hospital all patients had a cyst, in most cases tense or tender.

Table 1 Clinical data of a consecutive series of 8 patients operated upon for popliteal cysts through March 1976 (Series A). Communication closed by one row of sutures. No post-operative immobilization. For grading and follow-up see Methods

Patient no., age at op (years) sex	Associated disorder of the knee, remarks on the operative technique and findings at operation	Grading of subj. symptoms		Follow-up exam. by knee post-op.	
		preop	postop	at 1 yr	at 2 yr
1 36 ♂	Osteoarthritis with varus deformity	2	0	18	18
2 46 ♂	—	2	0	13	13
3 39 ♂	Two negative arthrographies. Clinical signs of chondromalacia of the patella	2	0	12	12
4 24 ♂	—	2	II	2	20
5 38 ♂	—	2	0	35	35
6 40 ♀	Operation in supine position. Closure of the communication after excision of ruptured medial meniscus. The cyst was left <i>in situ</i>	1	0	14	14
7 28 ♀	Severe rheumatoid arthritis. Anterior synovectomy 8 weeks before operation on the cyst	2	0	31	31
8 45 ♂	Severe rheumatoid arthritis. Anterior synovectomy 3 years before operation on the popliteal cyst	2	0	15	15

1) Follow-up arthrography was not performed in this patient as he suffered from a knee wound infection following excision of rheumatic nodules in the elbow.

Technique

Figure 2, Tables 1 and 2) With the patient prone and with a pneumatic tourniquet to the upper thigh, an 8-10 cm long, slightly curved skin incision was made, the easily palpable medial border of the semitendinosus tendon. The fascia was divided by exposing the semimembranosus the medial wall of the cyst. If fibrotic and the posterior wall of the cyst was dissected. The capsular opening was facilitated by the knee and thus relaxing the muscles on the individual anatomy, it was proceeded either anteriorly or posteriorly the semimembranosus tendon. On retraction of the tibia dorso-laterally the communication into view (Figure 3 A). It was concealed by thin synovial membrane folds, which were excised (Through

this incision the postero-medial capsule may be opened for additional intra-articular procedures.) The neurovascular structures in the popliteal fossa were protected by the broad muscle belly of the gastrocnemius. Very little bleeding occurred in these planes of cleavage.

Methods for closure of the communication In the early Series A (Table 1) the transverse opening in the capsule was closed by suturing the tendon of the medial head of the gastrocnemius muscle into the gap by a few non-absorbable mattress sutures. A suction drain was inserted and a light compression bandage was applied to the whole leg. Postoperatively joint exercises were instituted and all patients progressed to early full weight bearing ambulation.

In Series B (Table 2) a 1-2 mm thick and 1-2 cm long proximally based tendinous flap was raised from the anterior surface of the gastrocnemius tendon to cover the opening with some

Initial data of a consecutive series of 7 patients operated upon for popliteal cysts, September 1976 to May 1977 (Series B) Communication closed by gastrocnemius tendon capsuloplasty, postoperative immobilization in a plaster cast. For grading and follow-up, see Methods.

Associated disorder of the knee, remarks on the operative technique and findings at operation	Grading of subj symptoms		Follow-up		
			months postop	Recurrent cyst	
	preop	postop		clin exam	arthro-graphy
Osteoarthritis. The communication was closed by three rows of sutures	2	0	22	no	no
Patello-femoral osteoarthritis. Six osteocartilaginous loose bodies were found in the cyst (cf Figure 1), there were none in the joint	1	0	24	no	no
Operation in the supine position. Closure of the communication followed advancement of the tibial tuberosity for chondromalacia of the patella. The cyst was left <i>in situ</i>	1	0	24	no	no
Medial osteoarthritis, varus deformity	2	0	22	no	no
Medial meniscus excised 1957. Old rupture of the anterior cruciate ligament. Large loose body in the cyst	1	0	III	no	no
Operation on the cyst in the supine position was preceded by arthroscopy, which showed patello-femoral erosion	2	0	19	no	no
Osteoarthritis with varus deformity	III	0	15	no	no



Figure 1 Preoperative arthrograms (patient 10). The cyst has filled with contrast medium through the communication high up behind the medial femoral condyle. Six loose bodies were seen.

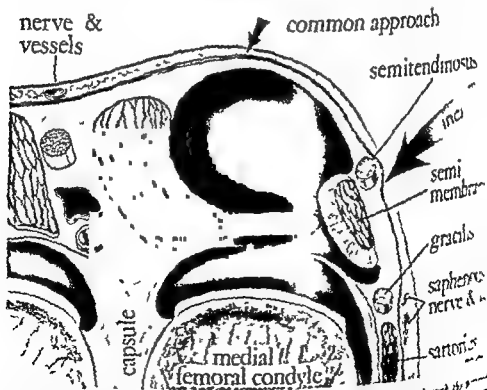


Figure 2 Surgical anatomy and approach. Schematic horizontal section through the medial quadrant of the knee joint at the level of the communication (dotted line) between the cyst and the joint. The semimembranosus muscle may be retracted either posteriorly or anteriorly for the opening.



The pedicle graft capsuloplasty as used in Series B. Retraction of the gastrocnemius exposes the capsular opening, through which in this case the osteoarthritic medial femoral condyle is seen. A proximally based flap is cut from the gastrocnemius tendon (here held in place by a forceps) and the flap is then sutured (B). Finally the tendon graft is lowered and sutured to the capsule for reinforcement at suture line (C).



1 The pedicle graft capsuloplasty as used in Series B (schematic sagittal section). Left: A proximally based flap has been raised from the articular surface of the gastrocnemius tendon. Right: The graft has been sutured to the capsule (see text).

overlapping (Figures 3 and 4). The capsular rim was scarified and then affixed to the base of the flap by a continuous atraumatic suture using non-absorbable suture material (Figure 3 B). (The flap should be cut prior to closure of the opening so as not to risk cutting the suture.) The flap then was let down on to the capsule trimmed to cover the thin area of the capsule and sutured to the firm capsular portion with interrupted non absorbable sutures (Figure 3 C). After release of the tourniquet and coagulation of active bleeding points a suction drain was inserted the deep fascia resutured and the wound closed and dressed. After turning the patient to a supine position, a plaster cylinder was applied with the knee in slight flexion. Postoperatively the leg was elevated early quadriceps setting exercises were instituted and the patients were allowed to walk about with full weight bearing usually without crutches.

RESULTS

Postoperative course (Series A and B)

The only complication was encountered in patient 6 who complained of sensory loss on the medial aspect of her lower leg and for 1 week her wound was red and swollen. A culture of the clear fluid discharging from the wound showed no bacterial growth. In the remaining patients healing of the wound was uneventful.

The total intra- and postoperative bleeding averaged 60 ml. Including the patients in whom additional surgical procedures were performed the mean length of stay in hospital was 4 days (range 1-11 days). Postoperatively in *Series A* slight to moderate effusion was noted for some weeks. In *Series B* the plaster and the skin sutures were removed 3 weeks postoperatively (6 weeks in patient 12). All wounds showed primary healing and a full range of knee movement was regained within a few weeks. No physiotherapy was required in any of the patients of either series.

Follow-up (Tables 1 and 2)

Clinical re-examination (Series A and B)

The average observation times in *Series A*

and *B* were 24 months and 21 months respectively. The symptoms popliteal space were assessed same criteria as described above.

There were no symptoms popliteal space and neither an aggravation of the arthritic signs. In patients 6 and 11 there had improved. According to the postoperative effusion had in or 2 months. Patient 6 had a hypaesthesia above the knee also a soft painless popliteal cyst.

Follow-up arthrography The *Series A* were examined by arthrography as described (Rauschning & Lindgren 1977) three recurrences (Table 1).

In *Series B* arthrography active provocation test, which increase the fluid pressure posterior capsule 10-15 ml of contrast medium (Lurografin 4 Schering) was injected into the joint on his side with the knee flexed. The patient was asked to try to knee against the examiner's resistance. Fluoroscopy and on the films of the suprapatellar pouch was examined posterior joint recesses. The posterior capsule (Figure 9) contrast medium from the joint in any case.

DISCUSSION

As popliteal cysts in arthritic secondary to an underlying joint disorder was therefore not possible. In patients 7 and 8 with toad arthritis the cysts had been anterior synovectomy in accordance with that of Jurek and Pinder (1973). They had no symptoms, however which were due to the hard fibrous dermal cysts. One torn meniscus was found



5 Follow-up arthrograms (patient 10 of Figure 1) 2 years after a pedicle graft capsuloplasty. Left: In passive flexion the contrast medium is evenly distributed between the anterior and posterior compartments of the joint. Right: On provocation (see text) the contrast fluid is forced from the suprapatellar region (arrow above) into the posterior recesses of the knee. There is no recurrence of the cyst.

patient patello-femoral disability necessitated an advancement tuberculo-plasty. The nodules contained in two of the cysts might have caused symptoms by mechanical irritation or pressure impingement.

Popliteal cysts in children were referred to surgery as several comprehensive studies in recent years have shown that as a rule these cysts constitute a harmless condition which troubles the parents much more than the patient, and that most infantile cysts disappear spontaneously (Fairbank 1969; Jahon 1973; Dinham 1975).

A modified approach to the deep portion of the cyst was worked out in earlier anatomical studies (Rauschnig 1979) and was applied in all operations and provided optimal access for suturing of the capsular opening. Incisions centred over the opening as described by most authors

(Haggart 1943; Justis 1971; Goldstein & Dickerson 1974, among others) yield poorer access to the gap (see Figure 2).

In Series A (Table 1) the communication was closed by suturing the tendinous belly of the gastrocnemius into the capsular gap with heavy non absorbable mattress sutures, a procedure similar to those previously described by a few other authors (Moser 1950; Solomon & Berman 1972). The only postoperative complication occurred in patient 6. She was operated on in the supine position which impeded optimal access to the communication. The postoperative swelling of her wound and the low-grade fever might be attributable to extravasation of synovial fluid from the joint, since the opening was not successfully closed (Rauschnig & Lindgren 1979).

In Series B (Table 2, Figures 3 and 4) a

reinforcement capsuloplasty was introduced. Studies of the surgical anatomy had verified that the postero-medial capsule is thin immediately distal to the slit-shaped opening and that the site of communication is subject to capsular tearing forces on active flexion and rotation of the knee. As the base of the pedicle graft from the gastrocnemius tendon is left intact, it presumably maintains its vascular supply and also eliminates the pull of the tendons on the sutures. Free tendon or fascia lata grafts have been advocated by Haggart (1943) and Childress (1970) for closure of the gaps, but apart from being avascular they are difficult to suture into the opening due to its anatomy. An additional suture of the semimembranosus to the gastrocnemius was advocated by Childress (1970) but this measure is felt to be of dubious value as it hinders active knee flexion and seems doomed to mechanical failure. The capsuloplasty used in *Series B* was easy to perform and the average operation time was 1 hour in both series. In *Series B* postoperative plaster immobilization was used in addition to the surgical reinforcement. This immobilization is perhaps not absolutely necessary for the prevention of recurrences, but is considered an advantage, as it will minimize postoperative haemorrhage resulting from tissue movements, probably eliminate tearing of the capsuloplasty during healing and also prevent undue distension of the posterior capsule by hydrostatic pressure which might occur on knee flexion. It also facilitates early ambulation. Three weeks of immobilization were considered adequate, as postoperative knee effusion usually subsides within this time.

No postoperative complications occurred in *Series B* and no recurrences were found although additional provocation manoeuvres were performed at follow-up arthrography. The average observation time of 20.6 months is admittedly short. However, numerous publications bear witness to the fact that recurrent popliteal cysts occur early, usually within a few months (Burleson et al. 1956;

Hoffman 1963; Rauschning & Leutenants among others). Moreover, a further 6 graft capsuloplasties have been performed on all these patients; they have made a complete recovery and show no clinical or radiological evidence of recurrent cyst.

No adverse effects from the denervation of communication were evident in the series — in particular no increase in the joint. No "compensation" occurred in the posterior synovial recesses as shown by follow-up arthrography. All patients regained a full range of knee motion within a short time, which can be attributed to the fact that the capsule was denuded of their bursal lining. Removal of the whole cyst is generally considered essential. This study would seem to indicate that a durable tight closure of the communication rather than radical excision of the cyst, is the decisive measure to prevent complications and recurrence.

CONCLUSIONS

- 1 This study confirms that popliteal cysts arise when excessive synovial fluid accumulates in the joint. In the knee joint is pumped over into a common space with the gastrocnemio-semimembranosus bursa.
- 2 In adults, a popliteal cyst is usually secondary to an associated distension of the joint which produces the effusion.
- 3 Popliteal cysts demand a thorough and careful examination of the joint by means of arthroscopy, if indicated, in order to detect any such associated distension.
- 4 At operation on the cyst the posterior capsule is approached by a postero-medial approach described in this paper greatly facilitates access to the communication.
- 5 The essential operative procedure is the closure of the communication by a pedicle graft excision of the cyst.
- 6 The pedicle graft is a free tendon or fascia lata graft performed in *Series B* with plaster immobilization relieved the pressure on the joint in all cases and led to no recurrences or adverse effects.

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H TIBIAL OSTEOTOMY WITH OVERCORRECTION VARUS MALALIGNMENT IN MEDIAL GONARTHROSIS

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Seventy-eight knee joints with varus malalignment were examined preoperatively using three-point measurement. Operation was performed with or without 5° overcorrection of the varus deformity using random selection. The overcorrection group showed significantly better results than the normal-correction group.

Key words: gonarthrosis, high tibial osteotomy, overcorrection, varus

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In the past 20 years osteotomy of the femur and tibia has been a generally accepted mode of treatment for gonarthrosis with malalignment (Jackson & Waugh 1961). The aim is to re-align the mechanical axis of the leg in order to distribute the load more evenly on the articular surfaces of the knee joint. The osteotomy is preceded by an X-ray examination to enable the surgeon to decide how much angular change will be needed. The purpose of this investigation was to determine the value of overcorrection of the varus malalignment in medial gonarthrosis.

METHODS

The degree of angular change required was determined by three-point measurement¹ (Edholm et al 1976, 1977). Patients were allocated at random to one of two groups.

Normal correction group — operation with an angular change equal to the varus/valgus deviation at three-point measurement.

Overcorrection group — operation with an angular change equal to the varus/valgus deviation at three-point measurement + 5° overcorrection.

If it could be predicted that after operation with overcorrection the articular surface of the tibia would be inclined more than 10° with respect to a line perpendicular to the long axis of the tibia, an angular change equal to the varus/valgus deviation was always made. Such patients were not included in the investigation.

At operation a wedge was resected between the tuberositas tibiae and the knee joint. No tightening of the joint capsule or ligaments was carried out. When necessary, resection of part of the fibular head was done to obtain close apposition between the surfaces of the osteotomy. Osteotomy of the fibular diaphysis was not done. Fixation was obtained with 1-3 staples. After operation the joint was stabilized with an anterior plaster slab. From the first postoperative day partial weight-bearing was allowed and quadriceps drill was carried out. From the second day gentle movement of the joint was encouraged. After 12 to 14 days the patient was fitted with a circular

Three-point measurement¹ is an radiographic X-ray technique for assessment of medio-lateral instability of the knee. The knee is taken in varus and valgus positions and the knee is fixed in a standardized way. In these positions films are taken over the hip, knee and ankle. Lines are drawn between the centre of the femoral head and the centre of the knee (hip-knee line) and between the centres of the knee and the ankle (knee-ankle line). The medio-lateral instability is measured as the angle through which the knee-ankle line has moved in relation to the hip-knee line between the two measurements. The varus/valgus deviation of the knee is defined as the angle between the hip-knee line and the bisector of the knee-ankle line, i.e. the bisector of the medio-lateral angle of instability.

knee plaster and allowed to go home. Six weeks after operation the patient was readmitted for removal of the plaster, X-ray, and physiotherapy. All patients were examined preoperatively and 3, 6, 12 and in most cases 24 months after operation by a surgeon and a physiotherapist using standardized tests of subjective and objective clinical variables and also by three-point measurement X-ray.

Wound infection was defined as secretion with or without positive bacterial culture. Pseudoarthrosis was said to be present when the osteotomy had not healed after 6 months. The chi 2 test, Student's *t*-test, and Fischer's exact test were used in the statistical evaluation of the results.

PATIENTS

and overcorrection groups (Table 1). There was no difference between the patients in the two groups with regard to degree of gonarthrosis and varus/valgus deviation at three-point measurement X-ray before operation.

RESULTS

Pain on weight-bearing was related to the degree of correction. In the normal correction group and in 89 per cent of the overcorrection group 55 per cent, respectively, were free from pain after walking 100 m (Table 2). This difference was not significant. With regard to postoperative pain after walking 1000 m and pain at rest there was no difference between the two groups. There was no significant difference in the ability to walk 300 m on an even surface against time.

Twenty-four months after operation the overcorrection group had significantly ($P < 0.007$) less starting pain than the normal correction group. The patients in the overcorrection group reported a better walking ability 12 months and 24 months ($P < 0.005$) after operation than the patients in the normal correction group. The patients in the over-

Table 1 Sex and age at the time of operation. One woman in the normal-correction group had been operated upon twice. Owing to random selection three women belong to both groups.

Group	Men	Women	Total	Age at operation
Normal correction	13	27	40	45-76 years
Overcorrection	19	18	37	40-75 years
Total	32	45	77	

Table 2 Pain on weight bearing. Before operation all patients had pain after walking 100 m.

Group	Pain before operation	1 year after operation			2 years after operation	
		No pain	Less pain	More pain	No pain	Less pain
Normal correction	100%	55%	75%	5%	61%	87%
Overcorrection	100%	69%	89%	3%	70%	117%

3 Patient's opinion about the result of operation at the final follow-up examination 1 or 2 years after operation

	Normal-correction Group	Overcorrection Group
than before operation	12%	5%
before operation	12%	8%
a better result than before	29%	16%
better than before	32%	43%
at all	15%	27%

were more satisfied with the result of operation (Table 3), the difference being significant ($P < 0.05$).

Results from both groups in whom correction of 3° to 7° resulted showed significantly ($P < 0.02$) better subjective results than patients from both groups in whom undercorrection was the final result. The means of the varus/valgus deviations by three-point measurement were 2.0° in the overcorrection group and 0.5° in the normal-correction group 1 year after operation. As the intention was to correct a varus/valgus deviation of 5° valgus in the overcorrection group and 0° in the normal-correction group, it is evident that the mean result in both groups was an overcorrection. The resulting varus/valgus deviation as found by three-point measurement differs significantly ($P < 0.005$) between overcorrection and normal-correction groups, however.

Joint mobilization under anaesthesia has been necessary. The patients quickly achieved satisfactory movement in the treated joint. At the 12-month follow-up examination joint motion had increased in 20 per cent, was unchanged in 77 per cent and had decreased in 3 per cent of the patients. The degree of flexion of the knee was increased by more than 5° in one-third of patients, unchanged in 47 per cent, and reduced by more than 5° in 17 per cent. The mean power of flexion of the knee was unchanged.

There were 6 (6.4 per cent) wound infections and 1 (1.1 per cent) pseudoarthrosis occurred. All wound in-

fections healed after antibiotic therapy. In one of the patients with wound infection a total hip replacement had previously been performed. Deep infection developed in the hip in connection with the superficial knee infection. In the patient with pseudoarthrosis, healing took place after extraction of the staples.

Manifest deep thrombosis of the leg veins occurred in two patients, the condition resolving in both after heparin treatment.

Fourteen (17.9 per cent) patients were subjected to reoperation. Two patients required a total knee prosthesis because of severe pain on weight-bearing in spite of good correction of the angular malalignment. In 12 cases the staples were extracted — in seven because they failed to stabilize the osteotomy, in three owing to local inflammation, and in two because the staples were judged to prevent healing.

DISCUSSION

Coventry (1973) used X-rays with the patient standing and weight-bearing on both legs for determining the size of the wedge to be resected. The angle between the long axes of the femur and tibia in the frontal plane was measured. Coventry's aim with operation for varus malalignment was to get an angle of 5° valgus between the long axes of the bones after healing.

All knee joints are unstable in the frontal plane, and the patient can move the knee into any position within the range of instability using muscular power. Coventry's method of evaluation of the intended wedge size will therefore not be reliable, as it is not known whether the patient is holding his knee in an extreme varus or valgus position or somewhere in between.

It is possible, however, that the knee will be in extreme varus when the patient is examined standing. If, therefore, a varus malalignment is corrected with the aim of obtaining an angle of 5° of valgus between the long axes of the bones, this angle plus the

total instability in that particular patient will probably be the resulting correction.

This difficulty can be avoided by restricting high tibial osteotomy to patients with a mild degree of gonarthrosis (Insall 1975) or by reducing the instability by tightening the lateral ligaments (Coventry 1973). Another possibility is to use the three-point measuring technique (Edholm et al 1976, 1977) which can be used to determine the instability of the knee.

When the intended size of the wedge has been determined the next problem is to excise the exact amount of bone at operation. This can be done with great precision with the aid of the SAAB jig (Myrner 1978). Sometimes, however, correction is partially lost after operation.

According to Coventry (1979) the question of whether to overcorrect a varus malalignment, and if so by how much, is still unsettled. In this investigation several different subjective and objective variables have been used in order to get an impression of the result of operation. Of the variables presented above, most significance is placed upon the patient's opinion of the result of operation at the final ex-

amination. The findings indicate that high tibial osteotomy for varus malalignment aims at overcorrection, but the exact aim should be aimed at in the individual case.

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- MYRNERTS

Knee joints were examined by three-point measurement (Edholm et al 1976, 1977). The instability in arthrotic joints did not differ significantly from that in normal knees. The increase in instability was measured by the difference between the normal and the postoperative values. The increase in instability was not significantly related with significantly poorer subjective results of operation. The findings indicate that shortening of the lateral stabilizing structures of the knee joint should be carried out in connection with high tibial osteotomy for varus malalignment. No upper limit of preoperative instability consistent with a good result of operation was established.

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but cannot define the degree of instability that can be accepted

This investigation was done to determine, (1) the degree of instability in the normal knee joint,

(u) the degree of pre- and postoperative instability consistent with a good result of operation, and

(iii) whether instability is aggravated by high tibial osteotomy

A new X-ray technique, three-point measurement, was used. In this the knee is brought into maximum varus and valgus positions in a standardized manner (Edholm et al. 1976, 1977). The angle in the frontal plane between the line from the centre of the head of the femur to the centre of the head of the tibia (hip-knee line) and a line from the centre of the head of the tibia to the centre of the tibial surface of the talus (knee-ankle line) is recorded. The difference between the angles obtained in the maximum varus and valgus positions is defined as the medio-lateral instability of the knee joint, and the mid-position between the maximum varus and the valgus positions is

called the varus/valgus deviation of the knee joint (Figure 1)

The three-point measurement technique was used to examine normal joints. The technique was also employed to examine knees with gonarthrosis before and 12 months after high tibial osteotomy for varus malalignment. The lateral structures were not shortened at operation in this series. At the final follow-up examination 12 to 24 months after operation the patients were asked how satisfied they were with the result.

MATERIAL

The series comprises 18 knee joints in young persons, 11 men and 7 women, who had undergone high tibial osteotomy (Table 1). All the affected joints showed focal medial gonarthrosis.

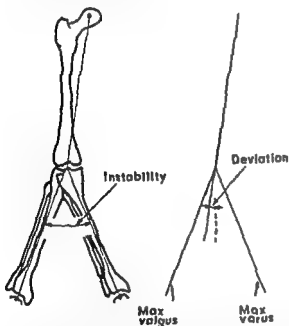


Figure 1 The three point technique for measuring instability and deviation of the knee. Varus deviation (+) is present when the bisector of the angle between the two lines is on the varus side.

Table 1 Age and sex distribution in the two groups

	Normal knees	Affected knees
Men	24	43
Women	24	56
Total	48	99
Age	22-54 mean 32	40-76 mean 62

RESULTS

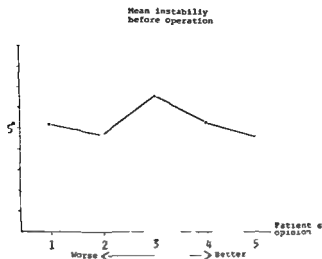
The mean of the varus/valgus deviation of the three-point measurement was close to the normal joints. Medial deviation varied from 0-9.5° (mean 4.6°).

The affected joints were more unstable than the normal ones (mean 5.1° - 1°-12.5°), but the difference was not significant. The mean of the varus deviations on three-point measurement differed significantly ($P < 0.001$) between the normal joints being in a varus position (mean 1-20.5° varus).

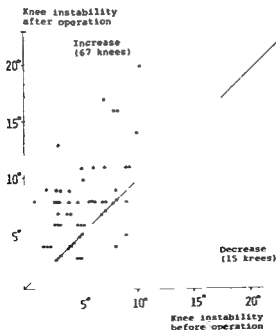
Knee instability before operation was confirmed that moderate instability and this material constitutes a contraindication for high tibial osteotomy. There was no relation between preoperative knee stability and good or poor results (Figure 2). The degree of preoperative instability varied from 0-12.5°, and this patient regarded the operation as relatively good. Preoperative instability sometimes occurred with a mean of only 3-4° (within the normal range). Some excellent results were obtained in patients with preoperative instability outside the normal range (7 patients, instability 1°-12.5°).

Before operation the knee was in a maximum valgus position showing a valgus angulation of 6.0° varus (range 2.1° - 17° varus). In maximum varus position the mean angulation was 11.6° valgus (range 0° - 24° valgus).

Knee instability after operation. The instability increased by 2.5° after operation (Figure 3). This increase was significant ($P < 0.001$). The increase in instability was carried with it a great deal of preoperative results (Figure 4). Preoperative instability of more than 2° showed significantly ($P < 0.01$) poorer results than those with an instability of less than 2°. Of the 10 patients showing an increase in instability of more than 5° had a pain free knee.



The patient's opinion of the result of operation related to the mean preoperative instability are graded.
than before operation
as before
's better than before
better than before
in at all now



The instability 1 year after operation as a function of the preoperative instability (94 knees)

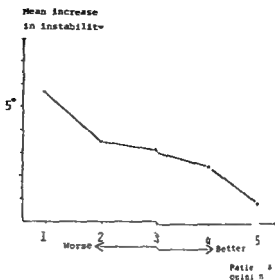


Figure 4. Mean increase in instability in relation to the patient's opinion about the result. Opinions are graded as in Figure 2.

DISCUSSION

The findings in this investigation do not indicate that moderate preoperative instability constitutes a contraindication to high tibial osteotomy for varus malalignment. No upper limit of instability consistent with a good result was established.

A significant increase in instability occurs in connection with the operation. Coventry's (1973) recommendation of shortening the lateral structures of the knee joint at operation is supported by these findings.

In medial gonarthrosis the varus/valgus deviation found by three-point measurement results from an increase in maximum varus angulation combined with a decrease in maximum valgus angulation. Only rarely will the maximum valgus position remain on the lateral side of the prolongation of the hip-knee line, probably because shortening of the medial collateral ligament makes passive abduction impossible.

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CLINICAL RESULTS WITH THE SAAB JIG IN HIGH TIBIAL OSTEOTOMY FOR MEDIAL GONARTHROSIS

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In 56 patients with medial gonarthrosis high tibial osteotomy was performed using the SAAB jig, and another 43 patients with the same

condition of the articular surface of the tibia on lateral X-rays when the SAAB jig was used. Operation using the device is not technically difficult, but is more time-consuming. The SAAB jig is a useful tool for achieving the predetermined correction in high tibial osteotomy.

Key words: gonarthrosis, high tibial osteotomy, operating aid.

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SAAB jig*, a device to facilitate high tibial osteotomy, is described elsewhere (Myrner 1978). The purpose of this study is to compare operation with and without this

METHOD

In knees a bone wedge of predetermined size was resected from the upper tibia using the SAAB jig.

Without the SAAB jig, by resecting a wedge with one of a series of wedge models or by use of the fact that a wedge base of 1 mm lateral corticalis of the upper tibia will give an angle of approximately 1° (Bauer et al 1969). The aim in all cases was to resect a wedge the size of which had been determined preoperatively by point measurement (Edholm et al 1976). X-ray examinations were carried out immediately after operation and 1 week, 6 weeks, 3 months, 6 months, and 12 months later. The

resultant wedge size was determined by measuring the angle between the long axis of the tibia and a line parallel to the articular surfaces of the tibial condyles on frontal X-rays of the knee before and after operation. Lateral views were used to detect any difference in the inclination of the tibial surface in the sagittal plane compared with that before operation.

At operation with the SAAB jig a new type of staple was used. Staple gliding was measured on frontal X-rays, and was said to be present when the staple had slipped outwards by more than 3 mm.

Wound infection was defined as secretion with or without positive bacterial culture.

At the final follow-up examination 1 or 2 years after operation the patients were asked how satisfied they were with the result.

PATIENTS

Fifty-six patients were operated on using the SAAB jig and 43 without this aid (Table 1). All showed focal medial gonarthrosis with varus malalignment. There was no significant difference in the groups with regard to sex, age, and wedge size.

*Journes about the SAAB jig should be made to Hille-Werner, Box 430 51, S-110 72 Stockholm, Sweden.

Table 1 Wedge size and age and sex of the patients in the two groups

	SAAB-jig	No SAAB-jig
Men	29	16
Women	27	27
Total	56	43
Age (mean)	61	63
Wedge size (mean)	9.8°	11.0°

Table 2 The difference between intended and obtained wedge size measured immediately after operation

Group/Difference	1°-2°	2°-4°	4°-6°	>6°
SAAB jig	60.3%	28.3%	5.7%	5.7%
No SAAB jig	42.9%	25.2%	11.9%	19%

Table 3 Increase in anterior inclination of the articular surface of the tibia measured on a lateral X-ray film immediately after operation

Group / Increase	0°-5°	6°-10°	>10°
SAAB jig	62.0%	26.0%	12.0%
No SAAB jig	28.9%	44.8%	26.3%

RESULTS

Operation time Operation with the SAAB jig was more time-consuming. The mean operation time was 76 min compared with 59 min for operation without the jig. The difference is significant ($P < 0.001$).

Exactness of wedge size The difference between intended and obtained wedge sizes measured immediately after operation was significantly ($P < 0.001$) less when the SAAB jig was used (Table 2).

Anterior inclination of the articular surface of the tibia On lateral films all but three patients showed an increase in anterior inclination of the articular surface of the tibia

Table 4 Complications and results

Group	Results
Wound infection	2 (3.6%)
Peroneal palsy	1 (1.8%)
Extraction of staples	7 (12.7%)
Reostentomy	0
Total knee replacement	3 (5.5%)

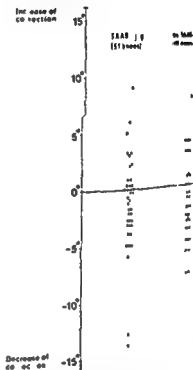


Figure 1 Changes in correction in degrees during the first year after operation.

Table 5 Subjective results of operation without the SAAB jig

Patients	Results
Worse than before operation	2 (3.6%)
No change before	16 (28.9%)
A bit better or than before	21 (37.9%)
Much better than before	22 (39.5%)
No pain at all	22 (39.5%)

after operation, and this was significantly ($P < 0.005$) fewer when SAAB jig was not used (Table 2). Increase in the anterior inclination

relation with good or poor subjective

g of staples Coventry staples (Coventry slipped more than 3 mm in 37 per cent of cases whereas the SAAB staple slipped less than 3 mm in 23 per cent. The difference is significant.

lications and reoperations The complications and reoperations encountered with or without the SAAB jig showed no significant differences (Table 4). The usual reason for reoperation was gliding.

of correction There was a tendency to overcorrection after operation both with and without the SAAB jig. Both groups include patients showing increase in correction and patients with loss of correction. There was no significant difference in loss of correction with or without the SAAB jig (Figure 1).

nt's opinion There was no significant difference in the subjective result between patients with and without the SAAB jig (Table 5).

On the X ray films an attempt was made to judge postoperative contact in the tibiotalar joint and the healing time. There were no apparent differences between operations with and without the SAAB jig.

DISCUSSION

In the present study the SAAB jig was used for high tibial osteotomy in normal correction and overcorrection, as determined by the three-point measurement technique. With regard to most variables investigated there was no significant difference between operation with and

without the SAAB jig. It is technically relatively easy to operate with this device, although the operation time is prolonged by 15 minutes. Operation with the SAAB jig did not in itself give a better subjective end result, but significantly greater accuracy was achieved. Use of the device resulted in significantly less anterior tilting of the articular surfaces of the knee.

It has been shown (Myrner 1980) that overcorrection of the varus malalignment at high tibial osteotomy for medial gonarthrosis gives significantly better subjective end results. It is therefore rewarding to aim at exactness and for this the SAAB jig should prove useful.

ACKNOWLEDGEMENTS

The author wishes to express his thanks to Professor Olov Lindahl for help and guidance throughout this work, and to Mr Henry Norrbohm for invaluable technological assistance in designing the SAAB jig.

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FAILURE OF THE CORRECTION OF VARUS DEFORMITY CORRECTED BY HIGH TIBIAL OSTEOTOMY

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Failure of the correction of varus deformity after high tibial osteotomy has been analysed in 99 knee joints. As this relapse occurred mainly after removal of the cast at 6 weeks, it is recommended that the patient should not load the affected leg without a cast until 10 weeks after the operation.

No patient-linked factor was identified that might be considered to account for the failure of correction during union.

There was a tendency for the valgus/varus deviation of the knee, as determined by the three-point technique, to drift in the varus direction. Between 3 and 24 months after the operation this drift was on average 1.1° .

Key words: failure of angular correction, gonarthrosis, high tibial osteotomy, varus.

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Success in corrective tibial osteotomy rarely equals the intended degree of angular correction in the frontal plane and how successful the operation was in this regard during the operation itself. A difference between the desired and the actual change in angle can arise. This is due in some measure to the difficulty of removing a bone wedge of the predetermined size. Another reason is that the wedge removed may be directed slightly forwards or backwards in relation to the frontal plane through the tibia, the result being that the angular change in the frontal plane that the removal of the wedge is intended to produce is partly lost.

Failure of the angular correction often occurs postoperatively. The time at which a relapse occurs has received little attention, likewise the responsible factors have not been dealt with. Ziller & Seyfarth (1974) found that in 17 out of 25 tibial osteotomies intended to correct varus deformity there was

an average change of 4° in the varus direction during the period of union. This figure is difficult to interpret because two radiographic variants were used, films taken with the patient lying supine immediately after the operation being compared with films taken with patient standing after union.

Possible causes of failure of correction are

- (1) Displacement of the osteotomy surfaces during union,
- (2) continued wear of cartilage and bone, and
- (3) changes in the stabilizing structures of the knee joint.

One purpose of the present study was to identify the factors that might be responsible for failure of the angular correction achieved at the operation. Another aim was to determine the time or times at which the relapse is likely to occur and to analyse the implications of the results for the postoperative treatment.

METHODS

Angular displacement of the osteotomy surfaces in

of the tibia, both drawn on frontal films. The angle was measured before and immediately after the operation and then after intervals of 1 and 6 weeks and 3, 6, 12 and 24 months. The standard deviation of the error of the method determined by replicate measurement on 10 films was 1° .

The medio-lateral instability of the joint and its varus/valgus deviation were determined by an orthoradiographic technique the 'three-point measurement' (Edholm et al 1976, 1977).¹ This determination was performed before the operation and 3, 6, 12 and 24 months afterwards. By the three-point method it is possible to measure the total angular change resulting from the surgical procedure involving both bone and soft tissue. By subtracting the above angular displacement from the total angular change that part of the change in the varus/valgus deviation that was due to the stabilizing soft tissues was isolated.

The patient's fat free weight (FFW) was determined from the expression $FFW = 1.2 + 162 L^2/R$ where L is the body length and R the sum of the widths of the right and left wrists (von Döbeln 1960) both expressed in metres. The normal weight (N) was taken as $1.2 \times FFW$ for men and $1.35 \times FFW$ for women (von Döbeln 1960).

The body weight determined by weighing was classified according to a 4-degree scale,

- 1 less than $1.1 N$ - normal weight
- 2 $\geq 1.1 N$ and $< 1.2 N$ - moderate obesity
- 3 $\geq 1.2 N$ and $< 1.3 N$ - marked obesity
- 4 $\geq 1.3 N$ - very marked obesity

The patients' age at the operation was recorded.

Knee joint mobility was measured with a goniometer.

The degree of arthrosis of the knee joint was estimated on frontal views of the joint taken with the patient standing on both legs with the knees slightly flexed (Marklund & Myrner 1974). The degree of arthrosis was classified according to the following 5 grade scale (Åhlback 1968).

Degree I At most a slight reduction of the cartilage height.

Degree II Obliteration of the joint space.

Degree III Bone loss of ≤ 7 mm measured along the medial or lateral margins of the joint

from a line perpendicular to the axis of the joint and tangential to the unaffected articular surface.

Degree II' Bone loss > 7 mm measured above.

Degree I Bone loss > 7 mm measured in the luxation position, defined here as the position of the tibia of a knee in relation to the femur.

The bone density was determined by absorption as described by Nyström (1974).

MATERIAL

The series for the study comprised 87 patients (57 women and 40 men). Their ages ranged from 47 to 76 years, mean 62 years (Table 1). In 67 patients the operation was performed as a total knee replacement giving 99 joints as the total material. In 20 patients the operation was performed as a partial knee replacement giving 20 joints. All the patients had a medial pre-arthrosis. The number of joints used in the various parts of the study (see below) differ because of the different number of patients performing the various examinations.

Table 1 Distribution of the patients according to sex, and age at the time of operation

Age	40-49	50-59	60-69	70-76
Women	2	11	27	17
Men	6	9	20	4
Total	8	20	47	21

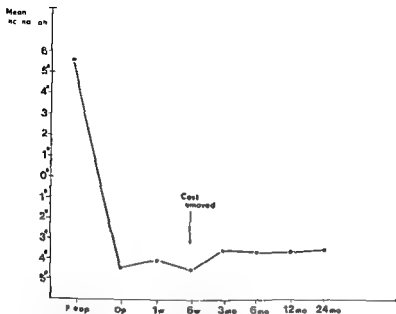
RESULTS

Failure of the initial correction of angular displacement

The change in the angular displacement of the articular surface of the tibia in the sagittal direction achieved at the operation was on average unchanged during the first 6 weeks but then there was a marked increase until the third month ($P < 0.01$). Subsequently the tilt remained constant until the end of the follow-up of 24 months (Figure 1).

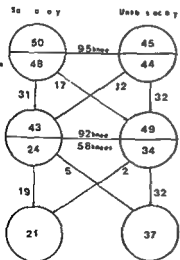
During the first 3 months after operation the tibial plateau tilt was on a mean of 0.8° medially (range 0° to 15° medially). From 3 to 6 months

¹ The varus/valgus deviation of the knee is defined as the angle between the hip-knee line and the mid position of the knee-ankle line i.e. the bisector of the medio-lateral angle of instability.



1 Mean inclination of the upper tibial articular surfaces in relation to a line perpendicular to the tibia before and at defined times after the operation

• medial inclination
• lateral inclination



2 Changes in the initial correction recorded on frontal films of the tibia. The 99 knees 92 were examined both initially and 6 months after the operation. Fifty of the 99 knees were examined at both 6 months and 24 months after the operation.

joints followed up for the full period showed on average a further 0.3° of medial tilt (range 5° laterally to 5° medially).

During the first 6 months after the operation there was a failure of correction in 17 of the 48 knee joints where the original correction was classed as *satisfactory* - that is to say the difference between the angular correction actually achieved and the intended apical angle of the wedge was not greater than $+2^\circ$ (Figure 2). Of the 44 knee joints where the correction at operation was *unsatisfactory* 26 were undercorrected and 18 overcorrected. In 12 of the knee joints with unsatisfactory correction due to angular displacement of the osteotomy surfaces in the frontal plane the correction improved and was then classed as *satisfactory* (Figure 2). As expected there was only a slight further deterioration after 6 months. Of the 37 joints where the correction was still unsatisfactory at 24 months, 20 were undercorrected and 17 overcorrected.

There was no statistically significant correlation between the postoperative failure of angular correction and any of the variables obesity, bone density, degree of arthrosis, age and instability of the joint. Nor was it evident that restricted mobility of the joint, manifested as a flexion contracture of more than 15° and restriction of full flexion to less than 90° , was associated with a medial change in the tilt of the tibial plateau.

Failure of initial angular correction as determined by the three-point technique

A satisfactory correction was recorded in 45 out of 91 joints 3 months after the operation. This was defined as a difference of not more than $\pm 2^\circ$ between the intended and the actual varus/valgus deviation of the knee as determined by the three-point technique. All the patients were followed up for 1 year and 60 per cent for 2 years. At 2 years the proportion of satisfactory corrections fell from 49 to 44 per cent. Of the 46 joints with an unsatisfactory correction at 3 months 42 (91 per cent) were undercorrected and 4 (9 per cent) overcorrected. Between 3 and 24 months the percentage with undercorrection varied between 88 and 95 per cent.

Changes in the varus/valgus deviation of the joint, as determined by the three-point technique, usually occurred as a displacement of both the valgus and the varus extreme positions. Between the 3- and 24-month follow-ups, a varus displacement of the varus/valgus deviation of the knee was recorded in 37 out of 55 joints, usually as a simultaneous increase in varus and decrease in valgus (18 out of 37). The mean displacement in the varus direction was 11° .

DISCUSSION

The analyses disclosed no single patient-linked factor that could account for the observed postoperative failure of the initial angular correction of the varus deformity. It is possible that combinations of the various

factors such as marked obesity, severe arthrosis and pronounced instability of the knee joint might prove to be more important in a larger series. Statistical analysis yielded no correlation between the various combinations of various factors in the study.

A constant drift in the varus direction after high tibial osteotomy observed by Insall (1976) is confirmed by the results of the present study. However, there was no correlation between the 3- and 24-month follow-up measurements of the varus/valgus deviation of the knee as determined by the three-point technique. It might be possible to prevent this drift in the future by placing more emphasis on the exercise of the muscles that stabilize the joint on the lateral side.

The cast was removed after 6 weeks and exercising of the joint was begun. The patient being advised to keep the knee in the neutral point where pain was felt. At the 24-month follow-up showed that displacement of the joint surfaces occurred between 6 and 24 months after the operation, which prolonged the period of treatment by 4 weeks so as to reduce the final correction during the first year.

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SILASTIC ARTHROPLASTY OF THE FIRST METATARSO-PHALANGEAL JOINT

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Twenty-nine patients were operated on for painful conditions of the first metatarso-phalangeal joint using Swanson's implant arthroplasty. In three cases the implant had to be removed. An analysis was made of the remaining 26 cases 4 to 6 years postoperatively based on a clinical and radiographic review. The results were deemed favourable and comparable to those attained by successful resections or osteotomies. The relatively high incidence of reactive bone changes, plus implant breakage in five cases, makes long-term results more uncertain.

Key words: silastic implant arthroplasty, great toe pain relief, reactive bone changes, implant breakage

Accepted 10 viii 79

In order to avoid certain disadvantages associated with the commonly used procedures for painful rigidity and valgus deformity of the first metatarso-phalangeal joint, Swanson in 1972 introduced an implant arthroplasty for the great toe (Swanson 1972). The implant is made of pliable silicone rubber (Silastic) in one piece and has an intramedullary stem to fit the first phalanx after a basal resection (Figure 1A). The pro-

sthesis is supplied sterile and is available in various sizes. It was used in 29 cases as an alternative to the Keller and Reverdin-Enström procedures. The survey is based on a clinical and radiographic review

Interval between operation and review averaged 5.3 years (range 4.8-7.2 months).

The indication for operation was painful valgus deformity or rigidity in 30 joints and rheumatoid arthritis in 4 joints.

In the interval between operation and review the prosthesis was removed in three cases leaving 26 patients (34 joints), 19 females and 7 males, for assessment.

Management. Basically a simple Keller procedure was performed. A fascial flap as recommended by Swanson was omitted. A canal was shaped in the proximal phalanx. The Silastic implant was used and fitted snugly against the cut surface of the phalanx.

After operation a pressure dressing and a splint were applied and worn for 2 weeks. Thereafter active motion was encouraged and full weight-bearing was allowed. A night splint was worn for 1 month.

The duration of stay in hospital was on the average 7 days for unilateral cases (range 3-14) and 8 days for bilateral cases (range 6-14).

Five patients were pensioners and four were either apprentices or were unemployed. In 20 working patients the duration of disability averaged 6 weeks (range 4-9 weeks).

PATIENTS AND METHODS

A total of 29 patients were treated with Swanson's Silastic arthroplasty of the first metatarso-phalangeal joint 4 to 6 years prior to study. Eight patients had bilateral operations, making a total of 37 arthroplasties. The age at operation was 53.6 years (range 41 years) and at review 59.2 years.

Table 3 Passive range of dorsiflexion in 34 metatarso-phalangeal joints

sis	Range of dorsiflexion			Total
	0°-20°	21° 40°	>40°	
valgus		4	9	13
rigidus	3	10	4	17
atoid arthritis		2	2	4
	3	16	15	34

Table 4 Radiographic incidence of new bone formation around the base of the implant

Time after operation	Time after operation		
	1 year	2-4 years	4-6 years
	7	4	4
	10	6	6
	10	11	19
	4	5	5
radiographed	3	8	0
	34	34	34

The radiograms were supplemented by roentgenography in the lateral projection (Hager)

of the 34 joints radiographed at follow-up. In 10 joints no signs of bone reaction around the implant or new bone formation and/or joint space narrowing of the phalanx. The degree of new bone formation was graded in three stages by measuring the encroachment upon the base of the implant (Table 4). After the first postoperative year or so, apparently a period of stress adaptation, encroachment was seen to increase in about a third of the joints but otherwise no further changes were observed. Encroachment was absent in four joints, two with rheumatoid arthritis and in two joints with implant fracture (vide infra).

In a review five cases of implant fracture were found. A common feature of four of these cases was that the postoperative

radiograms showed a space between the base of the implant and the resected surface of the phalanx (Figure 1A). This space persisted in two joints in which no encroachment of new bone was seen and in the two other joints the setting process was prolonged. Such incongruity apparently concentrated the forces acting upon the implant to the area of the junction between the stem and the base of the implant where cracks were found in all four cases (Figure 1B, C). In the fifth case a fragment from the dorsal edge of the implant



Figure 1 A Two months after operation for painful hallux rigidus B, C Frontal and lateral views of the same toe 4.5 years after operation showing breakage of implant

minor encroachment. Less than half of the thickness of the implant base.
moderate encroachment. More than half of the thickness of the implant base.
severe encroachment. The whole thickness of the implant base.

base had been pinched off at some time between 2.5 and 5 years after operation

CONCLUSIONS

In our opinion this method, at any rate 4–6 years after operation, compares well with more established methods. The number of dissatisfied patients was comparatively less than that reported by Goldie et al (1974) who reviewed 110 patients 2 years after Reverdin osteotomy or resection. Sixteen were not satisfied with the result (14.5 per cent) compared with 2 (7 per cent) in this material.

No attempt was made to compare the results of this survey with those of other methods, i.e. osteotomies and resections, performed by the same surgeons but the general impression was that this method afforded a higher rate of complete pain relief and good cosmetic appearance. Range of motion of the joint and the frequency of shoe problems, on the other hand, appeared not to differ appreciably

As there were two patients who developed persistent unaccountable pain resulting from removal of the implant and five implants showing breakage on radiograms, it is our opinion that the method in its present form should be used with caution particularly in younger patients. To avoid fractures of the implant a close fit between the implant and the resected phalanx is apparently of importance.

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TOMOGRAPHY IN THE DIAGNOSIS OF POSTERIOR DISLOCATION OF THE STERNO-CLAVICULAR JOINT

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A case of posterior dislocation of the sterno-clavicular joint is described in which tomography was helpful in confirming the diagnosis. It is suggested that this investigation may be useful where doubt exists in dislocations of this joint

Key words: dislocation, sterno-clavicular joint tomography

Accepted 4 xi 79

The sterno-clavicular joint is a diarthrodial joint which provides the only true articulation between the trunk and upper limb girdle. It is surrounded by strong ligamentous structures, and it is generally agreed that dislocation of this joint is uncommon, occurring in approximately 3 per cent of shoulder-girdle injuries (Baker 1958). Of the two varieties of dislocation, anterior and posterior, the latter is much rarer. While the clinical diagnosis may sometimes be obvious, with easily palpable deformity together with engorgement of neck veins, mild respiratory distress, and difficulty swallowing, radiographs in special projections (Baker 1959, Hobbs 1968) are usually required to confirm the diagnosis. The following case illustrates the value of tomography in this respect.

The medial end of the clavicle with some abnormal mobility, and an easily palpable "step" at the sterno-clavicular joint, the clavicle disappearing beneath the outer border of the manubrium. In this region a small, mobile soft-tissue swelling could be felt presumably the intra articular disc of the sterno-clavicular joint. A clinical diagnosis of posterior dislocation of the sterno-clavicular joint was made but routine antero-posterior and 40° oblique radiographs did not provide confirmation of this. Postero-anterior tomography of both sterno-clavicular joints was carried out, and clearly showed the medial end of the left (normal) clavicle coming into focus at a "slice" 1 cm anterior to that at which the medial end of the right clavicle came into focus (Figures 1 and 2). This was taken as confirmation of the clinical diagnosis, and under general anaesthesia reduction was achieved by abduction, traction and extension of the upper limb. The reduction was complete and remained stable. A figure-of-eight bandage was applied and the patient made an uneventful recovery.

REPORT

A 35-year-old male aged 15 fell onto his right shoulder while "jumping". He immediately experienced pain in the region of the right clavicle but was able to continue working and was admitted to the Accident and Emergency 4 hours later. At that time he complained of pain at both ends of the clavicle, slight difficulty in swallowing and upper chest pain on inspiration. There was marked tenderness at

DISCUSSION

While anterior dislocation of the sterno-clavicular joint usually presents no difficulty in diagnosis, with obvious prominence of the medial end of the clavicle, posterior dislocations may sometimes be less evident clinically, especially in obese patients. It is



Figure 1 Tomographic "slice" at 8 cm showing medial end of left clavicle in focus



Figure 2 Tomographic slice at 9 cm showing medial end of right (dislocated) clavicle in focus

stated that the pain associated with posterior dislocation is more severe than with anterior dislocation, but in the patient reported here pain was not an especially marked feature. This patient did complain (though not spontaneously) of slight dysphagia and dyspnoea, but there were no signs of venous congestion and no pneumothorax.

In view of the vital structures in direct posterior relation to this joint, it is important to obtain the best diagnostic information and clinical examination may be insufficient. There are anatomical difficulties in taking true lateral radiographs of an individual sterno-clavicular joint in either the sagittal or the coronal plane. The standard AP or PA projections or the various inclined views which have been described, may be difficult to interpret. It is suggested that where any doubt exists regarding the diagnosis of posterior dislocation of the sterno-clavicular

joint, or where detailed radiographic information is required (e.g. suspicion of associated fracture) accurate tomography is the most helpful tool.

ACKNOWLEDGEMENT

I am grateful to Mr J Spivey F.R.C.S. Consultant Orthopaedic Surgeon for permission to report this case under his care.

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ANNOUNCEMENTS

European Rheumatoid Arthritis Surgical Society
The inaugural conference of the European Rheumatoid Arthritis Surgical Society will be held in Vienna, Austria, from April 23-25,

For further information about the society or the conference, contact the President, Jan Pihle, M.D., Oslo Sanitetsforening, Rheumatism Hospital, Akersbakken 27, Oslo 1, Norway.

Volvo Awards for Low Back Pain Research
In order to encourage research into low back pain, the Volvo Company of Goteborg, Sweden, has again this year sponsored three awards of US\$ 3,000 each. Awards will be made competitively on the basis of scientific merit in the following three areas:

- 1. Clinical studies
- 2. Bioengineering studies
- 3. Studies in other basic science areas

Papers submitted for the contest must contain original material, not previously published. Multiple authorship is acceptable. The manuscripts should be full-length in a form suitable for submission to a scientific journal. Five copies of each paper submitted in full should be sent to the address given below, post marked *not later than January 2, 1981*.

One of the authors should be prepared to come to Paris, France, at the time of the meeting of the International Society for the Study of the Lumbar Spine, May 17-20, 1981, to present the paper and to receive the prize.

A board of referees will be chaired by the undersigned and will contain members from the fields of clinical medicine, bioengineering and biochemistry.

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MATE FAILURE OF DIAPHYSEAL BONE

Experimental Study on Dogs

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The fracture process of torsion tested entire canine diaphyseal bones was studied with a high speed camera. The speed of the final fracture propagation proved to be incompatible with plastic deformation of macroscopical parts of the bone.

Keywords bone bone strength biomechanics fracture stress mechanical

Accepted 8 xi 79

The torque-twist curve of entire diaphyseal bone from dogs consists of a linear part starting from zero load and a non-linear part preceding the ultimate failure of the bone (Fig. 1). The linear part of the curve characterizes the elastic deformation of the bone (Chamney 1970, Currey 1970). It has been assumed by many authors that the non-linearity basically corresponds to plastic deformation of the bone (Currey 1970, Farkas 1970, Burstein et al 1972, Pope & Frymoyer 1972).

The development of small cracks in the bone, however, has been pointed out previously by Frost (1960), Pope & Outwater (1970) and Carter & Hayes (1977a) among others. Microcracks formed during the non-linear phase of the deformation proved to reduce the bone stiffness to such an extent that the non-linear behaviour of the bone can be explained by this effect (Carter & Hayes 1977b, Netz et al 1979, 1980).

It has therefore been postulated that the bone material is elastic even in the non-linear phase, and that the non-linearity is caused by microcracks (Netz et al 1980).

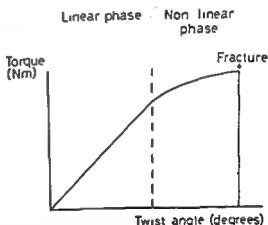


Figure 1 The torque-twist relationship of entire diaphyseal bones. The relationship is linear starting from zero torque and non linear preceding the final fracture. The magnitude of the torque is in newtonmetres (Nm) and that of twist in degrees.

Robertson et al. (1978) studied the fracture toughness of bovine bone material and found that the size of the plastic zone around the crack tip is less than 0.02 mm. On this basis, they concluded that crack propagation

involves localized disruption around individual or small groups of lamellae. This finding supports our suggestion that an elastic bone material is not incompatible with a non-linear load-deformation relationship.

The aim of the present work was to study whether plastic deformation of macroscopic parts of the diaphyseal bone occurs during the final fracture process.

MATERIAL AND METHODS

The test material consisted of related pairs of femora and of tibiae with closed epiphyseal lines from two healthy dogs. The animals were chosen at random from a group of 30 long-legged dogs of various breeds and of both sexes. The weight of the experimental dogs was approximately 15 kg. One bone from each related pair was selected at random as the test bone and the other as its control.

Immediately after sacrifice, all soft tissue was removed from the bones, which were kept moist at room temperature ($+20^{\circ}\text{C}$) in gauze saturated with physiological saline solution.

Torsion testing was carried out using the method and torsion machine described by Strömberg & Dalén (1976). The entire diaphyseal bones were fixed in the machine grips by casting the bone ends in two metal cuffs. The castings consisted of a metal alloy with a solidification temperature of 47.5°C . This technique prevented undue stress concentrations in the bone ends and made it possible to test the bone within 15–30 minutes after sacrificing the animal.

The torsion machine permits twisting of the test bone at a constant twist rate, irrespective of the load within the test range. The twist rate was fixed in the present study at 6 degrees per second. The torque as a function of time was registered on a multichannel light beam recorder (Ultralette 5651, ABEM, Bromma, Sweden).

For each related pair of bones, the control bone was first twisted to ultimate failure and the maximum torque capacity determined. Subsequently the test bone was twisted to ultimate failure. The last 2.5 seconds of this test, including the final fracture process, were registered with a high speed camera (HYCAM, K20S4AW, I. Weinberger, Zurich, Switzerland). The film speed was 5,000 exposures per second.

All bones were twisted outwards. The onset of the filming period was determined by the recorded torque-twist curve of the control bone (Strömberg

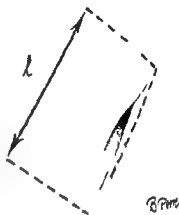


Figure 2. Measurement of fracture path. Assuming that the fracture propagates point in two directions only, one half of the fracture path was measured.

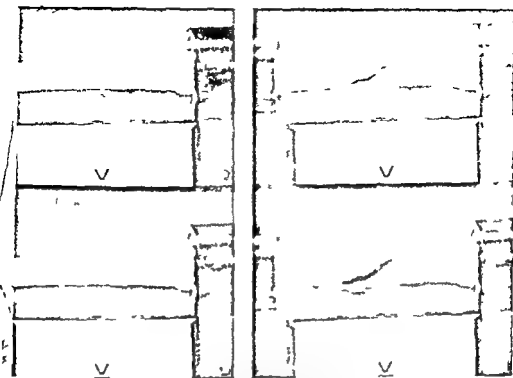
& Dalén 1976; Netz et al. 1978). High speed filming requires intense lighting of the bone to prevent the effects of heat due to the light. The bones were continuously sprayed with physiological saline solution during filming.

The length of the final fracture path measured on the test bones as indicated in Figure 2.

RESULTS

Exposures immediately before the failure of a bone are shown in Figures 3a and 3b, immediately after in Figures 3c and 3d. The exposures are consecutive in the order a, b, c, d, the time lapse between them being 1/500 seconds. Figure 3a as well as Figure 3b show a still unfractured bone. In Figure 3c, the final fracture is completed. The bones failed through the fractures.

The length of the fractures of the test bones and of the control bones (Figure 4) is shown in Table 1, together with the



3 Four consecutive high speed film exposures. The time interval between two pictures was 0.0002. The torque in relative numbers is shown on the potentiometer.

ited fracture propagation speed of the bone fractures. The intense lighting on the test bones did not seem to affect the maximum torque capacity or the final fracture as shown in Table 1.

DISCUSSION

Diaphyseal bone is a complex construction of heterogeneous materials. The distribu-

tion of cortical and spongy bone varies in different parts of the bone as does the distribution of inhomogeneities, such as blood vessel channels, medullary and resorbed bone cavities, etc (Currey 1962, Piekarski 1970, Robertson et al 1978). Microcracks connected with inhomogeneities have been observed by many authors (Frost 1960, Currey 1962, Piekarski 1970, Carter & Hayes 1977a). The reduction of the effective

Bone	Maximum Torque capacity (Nm)		Fracture path length (mm)		Fracture propagation speed (m/s)
	Control bone	Test bone	Control bone	Test bone	Test bone
Tibia	26.2	26.8	73	77	> 385
Femur	28.2	27.8	76	68	> 340

stiffness of the entire bone in the non-linear range (Netz et al 1979a) indicates that the number of microcracks prior to final failure is considerable. At present it is not clear whether or not their distribution is uniform in the entire bone. As the microcracks are more effective local stress raisers than inhomogeneities (Currey 1962, Piekarski 1970) it is reasonable to assume that they are decisive for initiation and propagation of the final fracture. The final failure process of the entire diaphyseal bone is accomplished within 0.0002 seconds. In spite of the film speed the time to fracture is too short to permit details of the fracture process to be discerned.

Assuming that the final fracture is initiated at one point and propagates in two directions, a lower limit of an effective propagation speed can be estimated at 340 m/s. It is, however, possible that the final fracture is formed through joining of local fractures initiated at different points. The true propagation speed of a local fracture may thus be lower than the estimated value.

The energy supplied to the bone during the final fracture process is insignificant. This means that the final failure is unstable and the fracture energy is supplied entirely by released elastic energy of the bone. The propagation speed of a main or of local fracture(s) depends solely upon the mechanical properties of the material and is independent of the test machine twist rate. In comparison with the time to failure, plastic deformation of macroscopical parts of the bone is a time-consuming process. Therefore only a very thin layer in the immediate neighbourhood of the fracture surface can be deformed plastically during the fracture process. This is also in accordance with the results of Chamay (1970) and Robertson et al (1978). The fracture process is typical for an elastic-cracking material. Plastic deformation of macroscopical parts of the bone during the fracture process must therefore be ruled out.

The results of the present study support a previous postulation, i.e., that an entire diaphyseal bone from an adult individual is

elastic for all torques, even in the range of the torque-twist curve and the final fracture process (Netz et al 1980). Plastic effects do not alter the behaviour of

(1978). They can not be ruled out, although they only occur in microscopic size (Chamay 1970).

ACKNOWLEDGEMENTS

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VANT INTERFERON TREATMENT AND THE LATE DEVELOPMENT OF CEREBRAL METASTASES IN A PATIENT WITH OSTEOSARCOMA

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A consecutive series of patients with osteosarcoma have been receiving adjuvant interferon therapy at the Karolinska Hospital in Stockholm. We report here a case of tibial chondroblastic Grade III osteosarcoma, a boy aged 17 years, who received interferon therapy for 15 months and survived more than 5 years. The first sign of tumour spread was multiple cerebral metastases – an observation suggesting an antitumour effect of human leucocyte interferon on osteosarcoma.

Keywords: adjuvant therapy, interferon, metastasis, osteosarcoma

Accepted 6 x 79

Notwithstanding the advances that have recently been made in the treatment of osteosarcoma, the prognosis remains poor, with a 5-year survival rate of well below 50 per cent (Cancer Treatment Reports, 1978). By the time the condition has been diagnosed as a malignant tumour spread to distant sites, usually the lungs – has usually occurred (Cancer Treatment Reports, 1978). There may be metastatic spread to bones including skull and vertebrae. Most metastases develop within 1 year of the onset of the disease (Sweetman et al 1971). Brain metastases are rare and they are usually a secondary rather than a primary manifestation of tumour spread. This article reports the unusual course of osteosarcoma in a patient receiving adjuvant interferon therapy for 15 months.

CASE REPORT

In May, 1971, a boy of 17 years with no known previous history of systemic disease noted swelling

of the left proximal tibial condyle. This was treated as a benign lesion and resection was performed in July of that year. Two months later there was a local recurrence. A block resection of bone 12 by 4 cm was performed and a bone graft was transplanted from the iliac crest. The free margins of the bone were small and it was doubtful whether the operation had been radical. Subsequently, a histologic diagnosis of osteosarcoma was made. A conglomerate of lymph nodes removed from the left inguinal fossa 1 month later contained no demonstrable tumour cells.

Eighteen months later there was a second local recurrence, and this time, on the basis of an open biopsy examination, the tumour was classified as a chondroblastic osteosarcoma Grade III. The patient was then included in the clinical trial concerning the effect of interferon on osteosarcoma that is being conducted at this hospital (Strander et al 1977). He was given daily intramuscular injections of 3×10^6 units of interferon for 1 month (Cantell et al 1974). Subsequently a mid femur amputation was performed. The interferon treatment was then continued with the same dose but now reduced to three times a week. It was

withdrawn in February, 1974. Early on there were some minor side effects such as pain at the injection site and fever, and later minor loss of hair.

Throughout the treatment the patient felt well, he put on 15 kg and was able to return to work. Monthly follow-ups, including lung radiography, showed normal conditions until April, 1975 when a right sided pneumothorax developed. Scintigraphy or lung tomography were not performed. Spontaneous remission followed, however, and after 1 month chest radiographs were normal.

In July there was a recurrence of pneumothorax in the same lung. The course was much the same as before and no special treatment was given. Four months later paresis of the left facial nerve and paralysis of the left arm were noted.

Cerebral scintigraphy, computed tomography and carotid angiography showed three separate tumours in the right cerebral hemisphere. Microscopic examination of stereotaxic biopsy specimens revealed osteosarcoma tumour cells. Further examinations, including lung films, whole-body bone scintigraphy and liver scintigraphy revealed no remarkable features.

The brain tumours were not accessible for surgery. The treatment consisted of irradiation with 39Gy, and high-dose cortisone directed at reducing the oedema (Dexamethazone, 8 g daily).

In July, 1976 more than 5 years after the tumour was diagnosed a single pulmonary metastasis was detected in the right lung, and death followed 3 months later. Autopsy disclosed one small

metastasis in the third lobar vein, confirmed the metastasis in the right lung across — and the cerebral metastases. No tumours were found in any organ, except liver. For a graphical summary of the present case history see Figure 4.

Histological findings

This case illustrates the difficulty in judging slides of osteosarcoma. The tumour was twice diagnosed as a benign lesion. Like the patient's age are typical of osteosarcoma.

In 1976 all cases of osteosarcoma were diagnosed between 1971 and 1974 were reviewed by a group of bone experts from UVA, Dahlin, Chief, Surgical Pathology, Los Angeles Hospitals, Mayo Clinic Rochester and Thomas, Chief, Laboratory of Pathology, Institute NIH Bethesda (Brostrom et al. 1977) using the histologic classification of Dr. Broders (Dahlin 1975; Broders et al. 1976). The original diagnosis of benign tumour made in 1971, was then changed to osteosarcoma. At the time there was a predominant chondroblastic picture, but parts of the tumour exhibited osteoblastic and fibroblastic features and no grading could be made (Figure 1). In the recurrence cell growth was more atypical and the tumour was assigned to chondroblastic osteosarcoma (Figure 2).

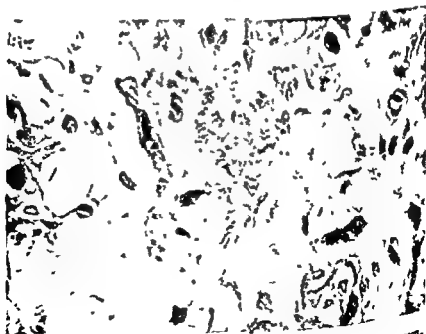


Figure 1 The first open biopsy in July, 1971. Tumour classified as osteosarcoma.



Figure 2 Open biopsy in the second recurrence Tumour classified as chondroblastic Grade III

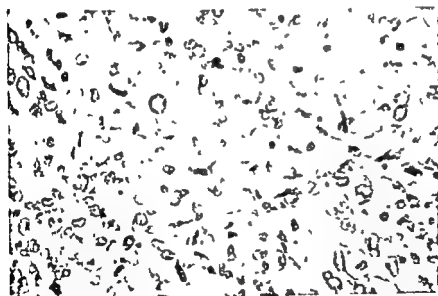


Figure 3 After 1 month of interferon treatment Regressive alterations in the cell picture can be seen.

specimens from the operation in January 1973. There were regressive alterations in the cell picture, necrosis and intracellular cavities. These were noticed after 1 month of interferon treatment (Figure 3). The autopsy slides revealed a local spread of osteosarcoma.

DISCUSSION

That this patient survived more than 5 years, when the osteosarcoma was treated initially as a benign lesion and recurred twice, is

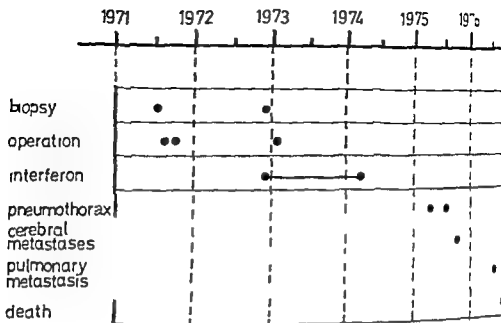


Figure 4 Summary presentation of the case history

remarkable. Previous reports suggest a more favourable course of the disease for patients with a long period of symptoms, which indicates a slower growth of the tumour (McKenna et al 1966). In the present case however an aggressive behaviour of the tumour cells was evident already in the original specimens. The regressive changes, with central necrosis found in the later specimens might be due either to fast growing cells or to some effect of the treatment. While the development of pneumothorax can in principle be a manifestation of metastases in the lung and pleura this can hardly have been the cause in our patient in view of the spontaneous remission on two occasions and the normal chest films and also in view of the very small metastasis in the right lung. This tumour was first confirmed 1 year after the first pneumothorax during a period of intensive cortisone treatment for the brain metastases. The first signs of tumour spread should have been the cerebral manifestations.

During the interferon treatment the patient felt well except for minor side effects, which are consistent with previous findings (Ingimarson unpublished results). It would

seem that there is a fairly effective penetration of interferon into the CSF and brain (Habif et al 1970; Jordan et al 1974). A further reason why the course of metastatic disease was not as aggressive as in other cases is that adjuvant chemotherapy was effective in the treatment of metastases in the lung than at other sites (Benjamin et al 1978). The course in this patient suggests that adjuvant interferon therapy did in fact have a beneficial effect.

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INDOMETHACIN AND ASPIRIN: EFFECT OF STEROIDAL ANTI-INFLAMMATORY AGENTS ON RATE OF FRACTURE REPAIR IN THE RAT

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A total of 210 male Charles River CD rats, 45 days old were subjected to a fracturing of the right radius and ulna by digital pressure while under ether anesthesia. These animals were then assigned randomly to dose groups (1, 2 or 4 mg/kg/day of indomethacin and 100, 200 or 300 mg/kg/day of aspirin) and were dosed for 21 days. Dose levels were chosen to provide approximately equipotent levels of the test compounds with the highest dose approaching toxicity. Radiographs were taken of control rat fractures

of the radius and ulna were examined in random sequence without knowledge of the treatment regimen. A histologic grade based on the morphologic stage of fracture healing was given. There was a drug- and dose-related retardation of fracture healing which was statistically significant at all dose levels of indomethacin and the highest level of aspirin as compared to controls. Decreased mean grades in the groups given 100 and 200 mg/kg/day of aspirin, though not statistically significant, suggest a retarding effect on fracture healing at these levels also. No statistically significant changes in numbers of pseudoarthroses were found.

Key words: anti-inflammatory agents, bone fractures, fracture repair, indomethacin, rats.

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ports have appeared in the literature suggesting that indomethacin may be useful in the rehabilitation of patients who have suffered fractures or who have undergone orthopedic surgical procedures (Bernstein et al 1977, Hsu & el-Salamouni 1968, Kudo et al 1973, Kurer & Weller 1969, LeClerc & Lissner 1969). However, recently some questions have been raised concerning the

possibility of delay of fracture healing by indomethacin (Huusko et al 1975, Rø et al 1976, Sudmann 1976, Sudmann & Hagen 1976). The present study was designed to determine whether the nonsteroidal anti-inflammatory agents, indomethacin and aspirin would retard healing of standard, unimmobilized, simple transverse fractures of the radius and ulna in the young rat.

MATERIALS AND METHODS

A total of 210 male Charles River CD rats 45 days old, were used. The rats were anesthetized with ether and were subjected to fractures of their right forelimbs. All forelimbs were broken using digital pressure applied over a fulcrum. Immediately after fracture, while still under anesthesia, the rats were radiographed using a Picker X-ray machine at 50 kVp, 48 mAs, on nonscreen, high-resolution (Kodak MA-2) sheet film. The films were developed in a Kodak rapid processing λ -omat and were examined to ensure that each rat had received a uniform, simple transverse fracture of the radius and ulna. Twenty-four hours after fracture, the rats were observed to ascertain that their limbs were not deformed, and were assigned randomly to dose groups. Dosing was begun on the day following the fracturing procedure.

Thirty rats were assigned to each of seven groups: 100 mg/kg/day aspirin, 200 mg/kg/day aspirin, 300 mg/kg/day aspirin, 1 mg/kg/day indomethacin, 2 mg/kg/day indomethacin, 4 mg/kg/day indomethacin, and control (which received only the vehicle, 0.5 per cent methylcellulose). The doses of indomethacin and aspirin were chosen to provide reasonably equipotent anti-inflammatory activity with the highest levels approaching toxicity. Indomethacin is considered approximately 100 times as potent an anti-inflammatory agent as aspirin in the rat (Winter 1964).

Dosing suspensions were prepared fresh daily. Indomethacin and aspirin suspensions were maintained on automatic stirrers throughout the dosing period.

The rats were housed in a room equipped with laminar airflow and constant temperature control. Purina Lab Chow and water were available *ad libitum* throughout the study, food was not withdrawn prior to autopsies. The rats were identified by consecutive numbers using indelible black ink on their tails.

On days 8, 14 and 21 rats in the control group were anesthetized with ether, and fracture sites were radiographed using the same procedure as described previously. The serial radiographs were used to determine the proper time for termination of the study when fractures in the control rats showed radiographic evidence of mineralized bridging of fracture sites; all surviving animals were killed and autopsied (day 22).

Rats dying prior to termination of the study were examined to determine the cause of death; no tissues from these rats were saved for histologic examination. One rat was found dead on day 22 and was included with the other rats killed at the

termination of the study. Those rats dying on day 22 were anesthetized with ether and exsanguinated for autopsy. Autopsies included removal of the fractured forelimbs by cutting the carpus and cubitus. The tissue was fixed in 10 per cent neutral buffered formalin. The bones were decalcified using 15 per cent formic acid; the radius and ulna were cut and embedded in paraffin to allow for 1 sections through the center of each callus.

All the histologic sections, stained with hematoxylin and eosin, were examined in sequence without knowledge of the regimen. The degree of fracture repair was determined using a 5 point scale. A grade of 1 was applied if there was complete bony union; a grade of 2 was applied if bony union was less than complete but the presence of a small amount of cartilage or callus, the repair was graded 3 (Fig. 1). A grade of 4 was applied if there was complete cartilaginous union (grade 2).



Figure 1 Incomplete bony union. Reveals partial plate of hyaline cartilage at fracture site (Grade 3) (Hematoxylin and eosin, 20x).



Figure 2 Complete cartilaginous union. A plate of cartilage traverses the callus (Grade 2) (Hematoxylin and eosin 33x)

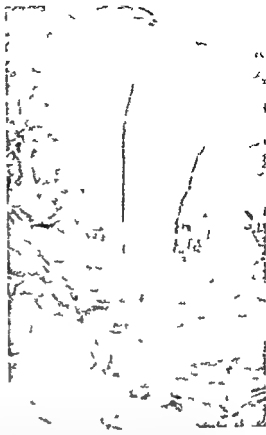


Figure 3 Incomplete cartilaginous union. Fibrous remnants remain within the callus (Grade 1) (Hematoxylin and eosin 33x)

ed present if there was a well formed plate of the cartilage uniting the fragments (Figure 2). Incomplete cartilaginous union (grade 1) was present when there was retention of fibrous remnants in the cartilaginous plate (Figure 3). The formation of a pseudoarthrosis (false joint) was a grade of 0 in that it indicated the most severe form of arrest in fracture repair a pseudoarthrosis (Figure 4). Pseudoarthrosis was considered present if there was an incontrovertible space within the cartilaginous plate between the fracture fragments, containing blood or other fluid and lined by low cuboidal mesothelium. The decision was based on the least healed bone (radius or tibia) however when a decision was equivocal (due to irregularities of sectioning) it was based on the synthesis of grades for both bones. The fracture repair scores were examined statistically by first re-expressing them in a rankit scale and then applying the appropriate analysis of

variance for overall comparison of rankit mean scores. The pairwise comparison between control and drug treated groups was accomplished using the least significant difference test ($P = 0.05$). The null or none data for pseudoarthrosis formation in treated rats were analyzed for possible treatment related differences using Fisher's (1 sided) Exact Test at the same level of significance (Harter 1961, McNemar 1969).

RESULTS

Two rats died prior to day 22, both of these animals were in the 4 mg/kg/day indomethacin group and both succumbed to midjejunal perforations with secondary peritonitis. A third rat in this group died of

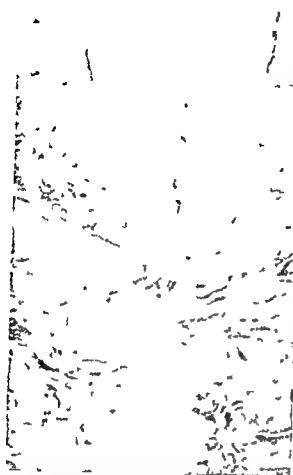


Figure 4 Pseudoarthrosis formation. A cavity partially lined by low mesothelium filled with proteinaceous material and blood is present within the cartilaginous plate (Grade 0). Hematoxylin and eosin, 33x.

intestinal perforation on day 22. The rat is a sensitive model for the effects and side-effects of the prostaglandin synthetase inhibitors, particularly indomethacin.

A distinct drug- and dose-related impairment of fracture healing was observed in both indomethacin- and aspirin-treated rats (Tables 1 and 2). A statistically significant decrease in mean fracture healing scores was observed at 300 mg/kg/day aspirin and at all dose levels of indomethacin. The decreases noted at 100 and 200 mg/kg/day of aspirin were not statistically significant but do suggest a considerable biologic effect. In addition, there was an increase in

pseudoarthrosis formation at 4 mg/kg indomethacin compared with control and other drug-treated groups as well. This was not found to be statistically significant.

DISCUSSION

The cause of the fracture retardation by anti-inflammatory agents is not fully understood. However, the inhibitory action of these compounds on prostaglandin synthesis may be an essential factor. Prostaglandins have been reported to enhance bone formation, and therefore possibly decrease bone production *in vitro* and in some *in vivo* systems (Dietrich & Raisz 1973). Inhibition of prostaglandins would therefore appear to have a salutary effect on bone repair. However, the vasodilatory effects of prostaglandins in the inflammatory (and the reparative) process would also be inhibited by the anti-inflammatory agents. Since bone formation requires adequate oxygen supply (cartilage and callus tissues are formed in oxygen-poor areas; Bassett 1962), the delay in ossification at fracture sites caused by prostaglandin synthetase inhibitors may be attributable to their depressive action on prostaglandin synthesis, hence control of regional blood flow (Staszewska-Barczak & Vane 1977). In addition, indomethacin has been reported to inhibit the activity of primitive osteoblasts (Sudmann 1975), although the effects of indomethacin on differentiated osteoblasts have not yet been fully studied. The retardation of healing occurs in the face of full weight bearing on the limb, which is known to accelerate fracture repair (Sarmiento 1977). A study of collagen metabolism in callus tissue from closed non-union femoral fractures in rats treated with indomethacin sufficient to delay fracture repair indicated that the delay was brought about by an inhibition of collagen synthesis (Rosen et al 1978). It should be pointed out that this is only a preliminary

Table 1 *Indomethacin/Aspirin Effect of nonsteroidal anti inflammatory agents on rate of fracture repair in rats Mean fracture repair scores in the various dose groups*

Treatment group	Mean score*
Control	2.53
Aspirin	
100 mg/kg/day	2.27
200 mg/kg/day	2.10
300 mg/kg/day	1.47**
Indomethacin	
1 mg/kg/day	1.73**
2 mg/kg/day	1.23**
4 mg/kg/day	1.11**

Slides read in random sequence without knowledge of treatment regimen * Based

**

($P < 0.05$) by least significant difference test

2 *Indomethacin/Aspirin Effect of nonsteroidal anti inflammatory agents on rate of fracture repair in rats Summary of fracture repair scores in the various dose groups*

Treatment group	Numerical grade	No. of rats with*				
		Pseudoarthrosis formation	Incomplete cartilaginous union	Complete cartilaginous union	Incomplete bony union	Complete bony union
		0	1	2	3	4
Control		1	2	11	12	4
Aspirin						
100 mg/kg/day		1	6	9	12	2
200 mg/kg/day		1	5	16	11	2
300 mg/kg/day		3	14	10	2	1
Indomethacin						
1 mg/kg/day		3	7	15	5	—
2 mg/kg/day		2	19	9	—	—
4 mg/kg/day		5	15	8	—	—

* Group contained 30 male rats 2 rats at 4 mg/kg/day indomethacin died prior to scheduled sacrifice All slides read in random sequence without knowledge of treatment regimen

bone repair since rats with fractures treated with indomethacin do proceed to full union in most cases (Wase, unpublished data)

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ELECTRIC POTENTIALS AFTER FRACTURE OF THE TIBIA IN RATS

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The aim of the present study was to analyse the changes in the bioelectric voltage with time after fracture until healing occurred. The right tibia of adult rats was fractured and every day during the first week, and then 10, 14, 21, 30 and 90 days after the fracture the bioelectric potentials were registered with callomelan electrodes placed on the anteromedial surface of the tibia. The data collected were statistically analysed. The biopotentials

early phase of callus formation

Key words biopotentials bone fracture healing time

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In the first reports of Fukada & Yasuda (1961) and Becker (1961) on electrical phenomena in bones, two lines of research have been followed. On the one hand the study of bone piezoelectricity and its relationship to Wolff's law, and on the other the analysis of bioelectric potentials and subsequent development of callus stimulated by electric or magnetic fields (Weigert 1973, Richez & Chamay 1972, Bassett et al 1978).

In a previous paper (López-Durán & Yageya 1978), the bioelectric pattern of the tibia in rats was found to be similar to that described by Becker (1961), Friedenberg & Hutton (1966) and Weigert (1973). The distal metaphysis shows a negative value which becomes positive in the middle of the diaphysis and remains so for the rest of the bone. After periosteal stripping we found an increase in the registered voltage, but the bioelectric pattern remained the same. Limb amputation only produced a decrease in the

collected potentials. When the bone was fractured a significant increase in voltage occurred along with a change in the electric spatial arrangement. The aim of the present study was to analyse the changes in the bioelectric voltage with time after fracture until healing of the tibia in rats.

MATERIAL AND METHODS

Under ether anaesthesia the right tibia of adult Wistar albino rats of both sexes was fractured by finger pressure. The fractures were located in the distal third of the tibia at the point of insertion of the fibula. Thereafter the rats were allowed to move freely in their cages under standard conditions. During the first week and then 10, 14, 21, 30 and 90 days after fracture the bioelectric potentials were recorded using callomelan electrodes as previously described (López-Durán & Yageya 1978). Before and after

bone repair since rats with fractures treated with indomethacin do proceed to full union in most cases (Wase, unpublished data)

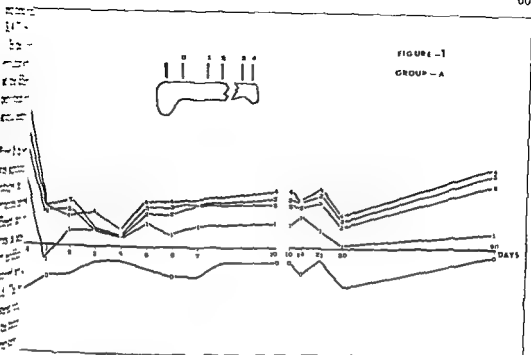
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1 Series A Evolution in time after the fracture of the average voltage values registered from 0 to 4 (IM = immediately)

1 Average voltages at various distances from the proximal epiphysis with increasing time after the fracture Series A

Time after fracture (days of rats)	Voltage in mV				
	0	1	Point 2	3	4
Immediately (7)	-3.033	6.033	7.829	9.329	10.571
Day (7)	-2.143	-0.486	2.129	2.471	2.571
Days (8)	-1.925	0.950	2.350	2.825	2.000
Days (6)	-1.000	1.167	1.000	1.133	2.267
Days (7)	-0.917	0.600	0.929	0.843	0.929
Days (7)	0.043	1.529	2.157	2.586	2.786
Days (8)	-1.950	0.800	2.137	2.637	2.887
Days (8)	-1.950	1.350	2.750	2.787	2.925
Days (14)	-0.957	1.693	2.800	3.107	3.671
Days (8)	-1.650	1.987	2.675	2.975	2.925
Days (6)	-0.800	1.183	2.817	3.250	3.630
Days (7)	-2.571	-0.100	1.457	1.729	1.957
Days (5)	-0.540	0.900	4.020	4.800	4.940
Control (18)	-3.642	1.176	5.367	5.539	5.472

every measurement the interelectrode voltage was registered and if greater than 2 mV it was balanced to zero.

The voltage was registered over the same points previously reported, as indicated in the figures. The reference electrode was placed over the proximal epiphysis, and the negative one moved sequentially from proximal to distal over both metaphyses, the proximal diaphysis and on each side of the fracture. Once the registration was finished, the periosteum was stripped off and a new series of measurements was made.

Thereafter the rats were killed with an overdose of Pentothal and the tibias were dissected free for histological studies. The tibias were fixed in 10 per cent buffered formalin phosphate. After decalcification and embedding in paraffin, the samples were cut in serial sections at 6 μ and subsequently stained with H.E. and Van Gieson.

The recorded voltage values in mV were subjected to computation to obtain the average values and the standard deviation for each group, and as the groups comprised less than 30 units, Student's test was used to compare data. If not otherwise reported in the text, only values of the order of $P < 0.001$ were accepted as significant.

RESULTS

The average voltage values of the registrations before removal of periosteum (Series A), the days on which they were recorded, and the number of rats included in each group are shown in Table 1 and are graphically represented in Figure 1. Table 2 and Figure 2 present the average voltage values at the same points and times in the same animals after the periosteum was stripped off (Series B).

We found some characteristics common to both series:

(1) During the entire period of the study, from the 1st to the 90th day after fracture, there was a decrease in the registered voltages which was most patent for points 1 to 4 (Figure 1).

(2) Both series, A and B, presented some oscillation of the recorded voltages. Series B showed more waves than Series A (Figures 1 and 2).

(3) The periosteum had during the earlier phases of repair a clear influence over the

registered potentials, especially for points 3, 4 (Figure 4).

In the following an analysis is made of the evolution with time of the registered voltages at the different points, the influence of periosteum upon them and the changes in the spatial electric pattern with time.

Point 0. In Series A the control voltages were significantly different from the registered voltages on days 3, 4, 5, 10 and 21. Variations between the values recorded on different days were not significant in this series. In Series B without periosteum no significant modifications of the registered voltages compared with the normal values were found. The periosteum did not influence the registered voltage at any stage and it is concluded that the fracture had only a weak effect on the registered potentials over the metaphysis.

Point 1. In Series A, only the voltages registered on the first day after fracture showed a significant difference from the normal value. For Series B, there was no difference between the control voltages and those registered on days 1, 6, 10, 14 and 21. There was also a clear difference between the voltage registered on day 6 and the voltages registered on days 2 and 5; this decrease in the registered voltages was statistically significant on day 6 after fracture. The difference between Series A and B after the periosteum is only significant for days 1 to 5 days and is negligible thereafter.

Points 2, 3 and 4. The behavior of the voltages in this series was almost the same. The significant differences which appeared during the whole period are shown in Table 1. At points 3 and 4 we found a significant difference between the normal voltage and the registered voltages immediately after the fracture and in the following days. In both series the distal metaphysis was the point where the influence of the fracture upon the registered voltages was most significant.

FIGURE - 3

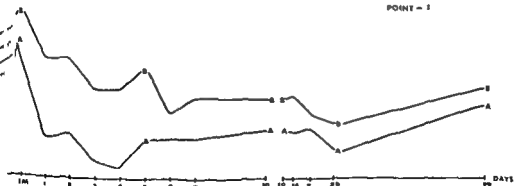
POINT - O



3 Evolution in time of the average values registered at point O Difference between Series A (periosteum) and Series B (without periosteum)

FIGURE - 4

POINT - 1



ure 4 Point 4 (representative of points 2, 3 and 4) Evolution in time after the fracture of average values and the influence of the periosteum upon the registered potentials

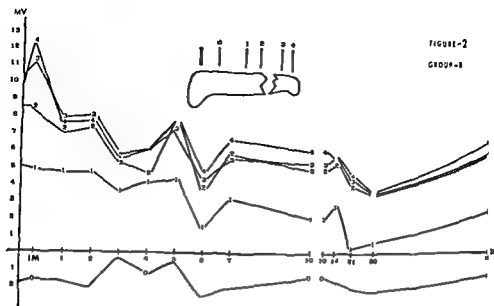


FIGURE 2

GROUP-B

Figure 2 Series B Evolution in time after the fracture of the average voltage values required points 0 to 4

Table 2 Average voltages at various distances from the proximal epiphysis with increasing time after the fracture, and after periosteal stripping Series B

Time after fracture (no of rats)	Voltage in mV				
	0	1	Point 2	3	4
Immediately (21)	-1 675	4 895	8 576	11 362	12 575
1 day (11)	-1 725	2 764	6 491	6 036	7 575
2 days (12)	-2 162	4 775	7 414	8 075	8 575
3 days (8)	-0 225	3 687	5 212	5 775	6 575
4 days (7)	-1 760	4 214	4 743	6 043	7 575
5 days (10)	-0 533	4 330	7 640	7 410	8 575
6 days (12)	-2 733	1 517	3 858	4 392	5 575
7 days (10)	-2 144	3 200	5 960	5 690	6 575
10 days (14)	-1 421	2 143	5 100	5 267	6 575
14 days (8)	-0 075	2 887	5 225	5 762	6 575
21 days (6)	-2 180	0 197	4 133	4 366	5 575
30 days (7)	-2 414	0 671	3 414	3 500	4 575
90 days (5)	-1 500	2 540	6 080	6 080	7 575
Control (28)	-1 814	5 086	9 543	10 335	11 575

and remained so until the end of the following some oscillations in the early repair.

Friedenberg & Brighton (1966) stated that after fracture there is an inversion in the polarity of the registered potentials with a maximum in the vicinity of the fracture zone and only a decrease in the recorded voltage which always remained positive and reached a maximum near the fracture site. Unlike Friedenberg, a normalization of the registered potentials was not found even 2 months after bone healing. This discrepancy perhaps can be explained by the fact that our measurements were made over the skin and bone whilst theirs were made over the skin.

The influence of the fracture tended to be localized around the fracture area, except in our study) the proximal metaphysis always showed a significant difference in the registered voltages compared with the voltages collected over the fracture and it was not possible to distinguish electrically one end from the other. The oscillations registered, especially those of Series A, are reminiscent of the voltage distributions described by Becker (1961) and Becker & Digby (1970) in amphibian limb regeneration. It is difficult to correlate the decreased voltage and the registered oscillations with histological and functional data in common. The callus starts immediately after the fracture as a violent cell proliferation over the fracture area and is first restricted to the fracture area 4 days later. This could possibly explain the voltage depression registered on day 14 in Series A (Figure 1), especially in view of the fact that there is a progressive decrease from cell proliferation to cell differentiation and vascular penetration during those days.

The persistence of a decreased voltage over healed fractures could be related to the remodelling process always active after fracture. The oscillations could also be related to callus stability, but this is a dynamic process and the biopotentials described here were registered on a static unstressed bone. The blood flow to the fracture area

increases immediately after the fracture (Paradies & Kelly 1973) achieving a maximum 10 days later and then falling to a plateau which is maintained until the 21st day after fracture. Friedenberg & Brighton (1966) suggested that negative voltages correspond to the most vascularized areas of the bone, and accordingly the callus should develop a negative voltage but we found only a decreased positive voltage over the entire tibia with the highest values around the fracture area. Digby (1966) considers that positive voltages correspond to centrifugal flow directions and negative voltages to centripetal flow. In the early stages of callus formation in displaced fractures of long bones, periosteal flow is greater than that of the medulla, and from the 14th–21st day onwards there is a reversion to predominantly medullary flow. This could possibly explain the recorded voltage oscillations. The predominance of the medullary flow over the whole callus from the 14th day postfracture can perhaps explain the reduction of the differentiation effect of the periosteum on the registered voltages. Since we have not directly analysed the relation between blood flow and the registered biopotentials, this statement on the relationship between the decrease in intensity and the callus stimulation by electric or magnetic fields remains to be proven.

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DERIVATION OF THE WRIST JOINT - AN ALTERNATIVE IN CONDITIONS OF CHRONIC PAIN

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Nine patients with chronic pain in the wrist secondary to lunatomacia and non-union of the scaphoid bone were treated by derivation of the wrist joint. This operation was first performed by Wilhelm in 1946. We have been using a modified technique. The purpose of the operation is to achieve relief of pain by selective neuromotor without impairment of hand function and with preservation of wrist mobility. Eight patients were considerably improved, one was not helped at all. No appreciable progression of the pathological changes have occurred radiographically during the period of follow-up. We find our results encouraging and the method worth trying.

Key words. derivation lunatomacia Wilhelm's derivation wrist joint

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Chronic pain in the wrist may be very annoying and frequently presents a difficult therapeutic problem. The pain may be due to early osteoarthritis, non-union of the scaphoid or posttraumatic changes following fractures of the distal end of the radius. Other causes may be due to lunatomacia (Axelsson 1955). In most of these cases there is no medical therapy. The surgical procedures which may be employed are merely of a corrective or symptomatic nature. Arthrodesis of the wrist is a well-established procedure with obvious disadvantage that it results in loss of joint mobility.

In 1938 Wilhelm presented a detailed clinical study of the derivation of the wrist. Eight years later the same author reported that effective relief of pain could be achieved by selective neuromotor of sensorial nerve branches to the joint capsule without impairment of hand function and with

preservation of wrist mobility (Wilhelm 1946, 1955).

At the Department of Orthopaedic Surgery, Västerås Central Hospital, this method has been used in a number of cases, and this paper reports our experience so far.

PATIENTS AND METHODS

Case material

During 1971-1975 nine patients were operated upon according to the method described below. Age, sex, occupation and diagnosis are presented in Table 1. There were seven cases of lunatomacia and two cases of non-union of the scaphoid. Symptoms had lasted for an average of 4 years (1.5-10 years). All had pain during manual work and five also pain at rest. Only two showed normal wrist mobility. Two had previously been operated upon but with poor results. In one of these arthrodesis had been performed and in

the other shortening of the radius and tenolysis. Eight had been using different kinds of wrist support during heavy work. Three of the patients had been taking analgesics continuously. It is shown in Table 1 that the patient's absence from work varied greatly. One had to change to a lighter job three times. The others showed a varying capacity for work. One patient attended a psychiatric hospital for a couple of months owing to a mental collapse caused by the constant wrist pain. All patients in this study were right-handed.

Surgical technique

The operation may be performed in different ways, varying the incisions and extent of denervation. Wilhelm recommends preoperative anaesthetic block of the nerve branches that are to be resected. We have not done this. All patients in this series have been operated upon according to the following modified technique.

The operation is performed in a bloodless field and with intravenous regional anaesthesia (IVRA).

1 We begin with a dorso-radial longitudinal curved incision, dissecting down to the dorsal

aspect of the radius proximal to the radio-ulnar joint. The posterior nerve is then located adjacent to the radius. About 3 centimetres are resected.

2 A transverse incision is made over the styloid process. The volar and dorsal branches of the superficial radial nerve are located. The articular branches are resected.

3 An S-shaped longitudinal incision is made on the volar aspect of the carpus. The transverse carpal ligaments are retracted, the flexor digitorum profundus is retracted towards the ulnar side of the border of the pronator quadratus. The median nerve is located. Here the anterior interosseous nerve is identified and resected for 3 cm.

4 A curved incision is made on the ulnar side of the wrist distal to the head of the ulna. The cutaneous dorsal branch of the ulnar nerve is identified and the articular branches excised.

All the cutaneous incisions are closed with sutures and a dorsal plaster splint is applied. The resected nerve branches are sent for verification.

Table 1 Age, sex, occupation and diagnosis

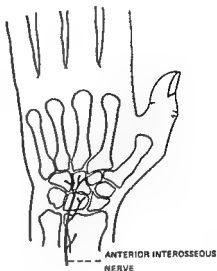
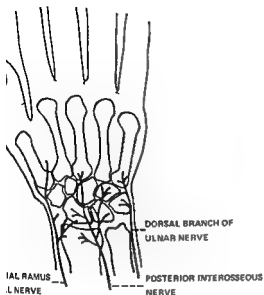
No	Sex	Age (years)	Occupation	Side	Diagnosis
1	F	53	Children's nurse	R	Lunatomalacia
2	M	49	Police inspector	R	Non union of the scaphoid
3	M	55	Cement worker	L	Lunatomalacia
4	M	25	Carpenter	R	Lunatomalacia
5	F	48	Factory worker	L	Lunatomalacia
6	M	42	Fitter	R	Lunatomalacia
7	M	44	B Sc (Econ)	R	Non-union of the scaphoid
8	M	29	Sawmill worker	L	Lunatomalacia
9	M	40	Weilder	R	Lunatomalacia

Table 2 Preoperative conditions

No	Mobility	Pain during work	Pain at rest	Duration of pain (years)	Side
1	Impaired	Yes	Yes	4-5	0
2	Impaired	Yes	No	10	3-6 cm
3	Impaired	Yes	Yes	2-3	8-11 cm
4	Impaired	Yes	Yes	2-3	6 cm
5	Normal	Yes	Yes	2.5	5 cm
6	Normal	Yes	No	1.5	0
7	Impaired	Yes	No	2	12 cm
8	Impaired	Yes	Yes	10	0
9	Impaired	Yes	No	1.5	

DORSAL ASPECT

PALMAR ASPECT



Innervation relevant to the operative procedure

DORSAL ASPECT

PALMAR ASPECT



2 Recommended lines of incision

define a denervation of this extent as a total if only the posterior interosseous nerve is divided we call it a partial denervation. Figures 1 and 2 demonstrate the details of the denervation and the incisions.

Postoperative course

Apart from slight superficial infection of the wound in one patient no postoperative complications were seen. A plaster splint was worn for

an average period of 3 weeks (Table 3). In one case the splint was worn for a much longer time because previous operations had given poor results and we therefore decided to prolong the immobilization in this patient.

Follow up study

The follow-up study was performed at Mölndal Central Hospital. All patients were examined by two of the authors on the same occasion. A detailed analysis of the conditions before and after the operation and a careful clinical examination were carried out. The latter consisted of a full neurological and anatomical examination of the upper extremity compared with the healthy side. X-ray films were taken of both wrists by the same radiologist and the films were studied jointly by him and the authors.

RESULTS

Results are listed in Table 4. One patient with light work went back to work immediately after the operation while another six patients could not return to work until 6-8 weeks after the operation. The patient who was splinted for 15 weeks because of previous postoperative difficulties did not return to work until 6 months after the operation. Most of the patients considered they had good strength, either normal or improved, in the operated wrist. Three reported reduced strength, which they had suffered from even before the operation. Measured objectively a slight or moderate reduction in strength was found in all

patients except one who had no strength.

All patients were found to have sensibility and sudomotor function. Swelling of the wrist joint was observed in four patients. One of these patients considered the mobility normal and one experienced an improvement in reduction. Objectively an improvement was noted in four cases, no change in one and reduction in four. None of the patients had a normal range of wrist mobility except the unaffected joint although, as mentioned above, some patients subjectively had it. In five patients we found crepitation during wrist movements.

Eight no longer suffered from pain. One complained of slight pain during changes in the weather and in one pain remained unchanged. Eight patients were free from pain during normal manual work. Three complained of slight pain during work periods when changes in the weather occurred. Two experienced slight pain during manual work. In one case the pain was unchanged.

Six patients were able to return to their former occupations. Two were given new duties. One patient changed to a new occupation, but he had already done this before the operation.

From an overall viewpoint there was convincing improvement in all cases. Four patients were very satisfied and one operation four were satisfied and one was not.

Table 3 Postoperative course

No	Type of denervation	Time in plaster splint (weeks)	Still leave
1	Total	3	8 weeks
2	Partial	4	8 weeks
3	Total	2	6 weeks
4	Total	15	6 months
5	Total	3	8 weeks
6	Partial	3	8 weeks
7	Total	3	2 days
8	Total	3-4	Cannot be evaluated
9	Total	3	7 weeks

Table 4 Results of the follow-up

No	Interval between operation and follow-up in months	Subjective strength	Objective strength	Pain at rest	Pain during work	Subjective wrist joint mobility	Objective wrist joint mobility	Sensibility
1	14	Slight reduction	Slight reduction	No	Only when change in weather	Normal	Better	Normal
2	19	Good	Slight reduction	No	No	Increased	Better	Normal
3	33	Good	Slight reduction	No	Only when change in weather	Normal	Better	Normal
4	23	Good	Slight reduction	Only when change in weather	Only when change in weather	Normal	Better	Normal
5	37	Good	Normal	No	No	Normal	Reduced	Normal
6	10	Good	Moderate reduction	No	Only during heavy manual work	Normal	Reduced	Normal
7	28	Good	Slight reduction	No	Only during very heavy manual work	Reduced	Reduced	Normal
8	25	Moderate reduction	Slight reduction	Yes	Yes	Normal	Reduced	Normal
9	24	Slight reduction	Slight reduction	No	No	Reduced	Unchanged	Normal

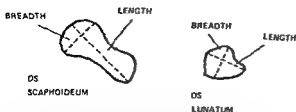


Figure 3 Measurement and calculation of quotient. The greatest diameter (length) is multiplied by the greatest perpendicular diameter (breadth)

Radiographs were taken of both wrists. The antero-posterior projection was chosen for evaluation because it is more difficult to define the different bones in lateral projections. The maximal length and breadth of the affected bone were measured on radiographs taken at the follow-up examination and on preoperative radiographs when available (Figure 3). The following quotient was calculated: Length \times breadth measured at follow-up divided by length \times breadth preoperatively. The same quotient was calculated for the healthy wrist joint. A quotient of 1.0 thus means that no change in the volume has occurred. A quotient < 1 indicates a volume reduction. Four out of eighteen quotients could not be calculated for technical reasons.

The X-ray evaluation showed unaltered conditions apart from insignificant reductions in four cases. Thus the denervation did not lead to Charcot-like changes in the joints.

DISCUSSION

In 1966 Wilhelm presented his method of denervation which he had performed on 21 patients. They had all been tested before operation and according to these tests different nerve branches were resected. The average time of follow-up was 16 months. He reported good or excellent results in 17 cases. Eleven years later Buck-Gramcko (1977) presented a much larger follow-up study consisting of 195 patients operated upon by seven German and Swiss hand surgeons. The

average follow-up time here was 11 years. Preoperative tests were performed in 169 cases. He found 69 per cent of the patients to be practically free of pain. Twenty per cent were only slightly improved and 11 per cent were not helped at all. None of the patients showed evidence of a Charcot joint. The indications for the denervation were similar to the reports for most of the patients. The same as we used, i.e. lunotriquetral union of the scaphoid bone.

As can be seen Wilhelm reported a high percentage of successful cases. This may be that Buck-Gramcko dealt with long-term results and some patients initially experienced pain which later developed a recurrence of pain.

In the nine cases presented here the denervation procedure was simplified. We found it sufficient to resect four nerve branches out of the 10 capsular branches as described by Wilhelm. With this method the preoperative test is unnecessary. The average follow-up interval was 22 months which is longer than Wilhelm presented, but less than in the report of Buck-Gramcko.

Eight patients improved considerably. They now have a painless wrist with preserved mobility under normal conditions. Only one was not helped at all. This is compared with Wilhelm who reported improvement in 17 cases out of 21 and Buck-Gramcko who found good results in two thirds of his patients.

Our material is small but we find the results encouraging and consider this method well worth trying. With our modified surgical procedure is simplified and operation trauma reduced.

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SCANNING IN LUMBAR DISC HERNIATION

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^{99m}Tc methylene diphosphate was used for whole body scanning and linear multiplane tomoscanning in 10 patients with typical clinical symptoms of prolapsed disc, in order to investigate whether there would be an increased focal accumulation corresponding to the bony structures adjacent to the affected disc.

The diagnosis of a prolapsed disc was confirmed by amipaque myelography, carried out in 9 patients, and finally verified at operation.

In none of the 10 cases could accumulation of radioactivity in the bony structures of the affected lumbar segment be demonstrated. Consequently this method has not been adopted for the diagnosis of prolapsed lumbar discs.

However it was demonstrated that ^{99m}Tc methylene diphosphate scintillography is useful in the differential diagnosis of ankylosing spondylitis and discitis.

Key words: disc herniation, lumbar spine, multiplane tomoscanning, technetium 99 whole body scanning

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It is well known that inflammatory conditions of the spine and joints result in an increased accumulation of ^{99m}Tc methylene diphosphate (MDP) (Handmaker & Merrick 1976, Merrick 1975) and it has also been established that an accumulation of radioactivity may be found together with signs of degeneration in the spine (Bergbom et al 1978, Liden & Loken 1974, Johannsen et al 1979).

By using multiplane tomography it should be possible to produce a series of tomograms at varying depths from the surface in order to obtain more accurate diagnostic information (Rae & Anger 1974).

Working on the assumption that degenerative and possibly inflammatory changes in the involved disc and adjacent vertebral bodies are part of the pathogenesis

of the prolapsed vertebral disc, we investigated whether with the aid of this method we could show increased focal accumulation corresponding to the bony structures adjacent to the affected disc.

PATIENTS AND METHODS

The investigation involved 10 patients with typical clinical symptoms of a prolapsed lumbar disc.

Amipaque myelography, ^{99m}Tc MDP linear scintillography and whole body scans were carried out.

In addition to these 10 patients, 15 patients were examined. There were three with symptoms of prolapsed lumbar disc who had not undergone surgery, two with disc degeneration, defined as radiologically proven narrowing of the disc space,

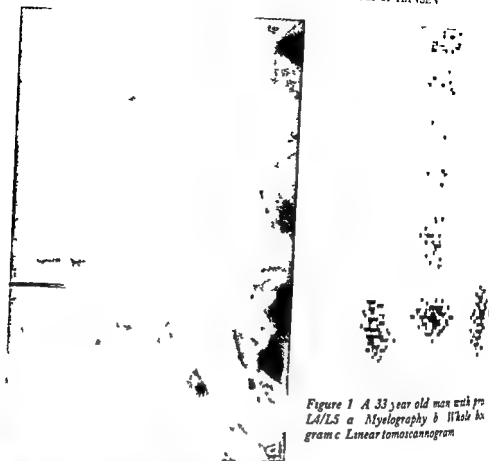


Figure 1 A 33 year old man with prolapsed L4/L5 a Myelography b Whole body scintiscannogram c Linear tomoscannogram



three with clinical and radiological discitis, three with clinically and radiologically proven ankylosing spondylitis, one with pain without signs of root compression, signs of prolapsed disc but the scintiscannogram insufficient and two patients with osteoarthritis.

^{99m}Tc MDP (kit from the Radio Centre Ltd, Amersham) on average (17.9–21.0) was given intravenously. The linear tomoscannograms were carried out at depths of 3 cm, 6 cm and 9 cm, and measured over the lumbar spine from L1 to L5. A scintiscannogram was used. The whole body scintiscannograms were obtained with a Pho/gamma scintillation camera.

Both linear scintiscannograms and whole body scintiscannograms were interpreted by one of the authors without prior knowledge of the history or the diagnosis.

RESULTS

The patients involved are two women and eight men between 29 and 53 years of age with surgically proven prolapsed lumbar discs.

f the 10 patients had, prior to surgery, graphically proven prolapsed lumbar n the remaining patient myelography ot indicated because the level of the was obvious clinically the patients had had an X-ray of the r spine and 50 per cent showed vng of the involved disc space in- ng disc degeneration

† results of a typical case showing graphy, whole body scanning and linear ing are illustrated in Figure 1a, b, c In on three patients with clinical oms of herniated lumbar disc were ined, none of them showed illographic accumulation

† comparison the three patients with al and radiological signs of discitis were ined Very prominent pathological nulation corresponding to the affected and the adjacent bony structures was d in all three (Figure 2)

re patients with active ankylosing dylitis showed pathological accumulation sponding to several intervertebral spaces vertebral bodies, in addition to the typical ological accumulation found in the area of tro-iliac joints (Figure 3)



Figure 2 Linear tomoscannogram of a 49-year-old woman with discitis L4/L5



Figure 3 Linear tomoscannogram of a 25 year-old man with ankylosing spondylitis

CUSSION AND CONCLUSION

many instances localization of the level of olapsed lumbar disc is problematical and -rent methods have developed in an mpt to improve the diagnostic accuracy y examination, including tomography, een shown to be inadequate (Magora & wartz 1976, Schalimtzek 1958) -rmography, epidural venography and dis- raphy signify progress but are not ciently accurate and/or give rise to nificant side-effects (Drasin et al 1976 gora & Schwartz 1976 Masare 1976, kin et al 1976)

Myelography is associated with a number subjective discomforts and side-effects so t a less taxing and an equally precise

method of examination is required (Ratjen 1977, Shapiro 1962, Spangfort 1972)

The question we posed was whether bone scintillography could be used in place of myelography for localizing the level of a prolapsed lumbar disc. Our investigation proved to the contrary

Scintillography can, however, contribute to the differential diagnosis when patients present with pain in the lumbar spine. In inflammatory conditions such as discitis and ankylosing spondylitis there is pathological accumulation of ^{99m}Tc MDP. The same has been demonstrated in numerous examinations of neoplastic conditions of the spine. However, with a prolapsed lumbar disc a positive scintillogram cannot be expected.

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BI-ILATERAL FEMORAL NECK FRACTURES AS A COMPLICATION OF MYELOGRAPHY

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This paper discusses two cases of bilateral subcapital fracture of the proximal femur as a complication of myelography with Conray 60. The literature is reviewed.

Key words: arthroplasty, fractures, myelography

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Myelography with water-soluble radiocontrast substances such as sodium monoiodohexahydrophosphates (Abrodil, methiodal sodium, contrast U), the toxic properties of these substances can cause side-effects of varying intensity (Praestholm 1979, Penning 1970, Bonsette 1971, Hugander 1974). Less toxic substances such as meglumine iodothalamate (Conray 60) and meglumine iocarmate (Dimer X) also have side-effects, but less frequently (Bonsette 1971, Skälpe 1971, Morrey 1977).

These side-effects can be subdivided into three groups: meningeal reactions, radicular symptoms and hyperexcitation phenomena (Bonsette 1971). The latter group includes myoclonic contractions, convulsions and epileptic seizures, which according to the literature occur in 8 to 19 per cent of cases after lumbar myelography with the above-mentioned substances (Hurteau 1954, Ahlgren 1959, Penning 1970, Skälpe 1971, Morrey 1977).

That these muscle spasms can cause severe complications is illustrated by the following two case reports.

CASE REPORTS

Case A

A 37-year-old woman who 1 year previously had been operated on for lumbar disc herniation was

admitted for lumbar myelography. Persistent low back pain had long confined the patient to bed.

Finally she was admitted for further evaluation on the suspicion of a radicular syndrome.

Without premedication myelography was performed, using 6 ml Conray 60 diluted with 4 ml CSF. The radiopaque substance was allowed to flow no higher than level T12-L1. A possible disc hernia was seen at level L4-5. After myelography the patient was returned to her room and placed prone in bed. One hour later she suddenly developed severe muscle spasms in both legs, and heard a snapping noise, after which pain developed in both inguinal regions, radiating down into both legs. During these severe tonic spasms, causing flexion of the spine and hips, she received no medication. In view of the persistent pain, a radiological examination was made which revealed bilateral medial femoral neck fracture.

The neck fractures were treated by osteosynthesis using Smith-Petersen nails. Several years later bilateral femoral head necrosis developed, for which she was treated by total hip arthroplasty (Figure 1).

Patient B

A 40-year-old athletic man, complaining of low back pain for the past 9 years, was treated on suspicion of lumbar disc herniation by complete bed-rest for a period of 3 weeks.

Because of persistent pain he was hospitalized for myelography. Before the examination, 20 ml Valium (diazepam) was given i.m. as premedication. The myelography was performed using 4 ml Conray 60 and 8 ml CSF and revealed an impression at level L4-L5, typical of a disc herniation.

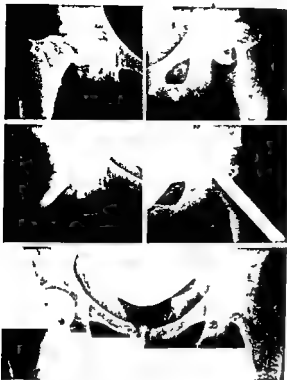


Figure 1 Both hips of patient A, shown successively after the accident, after osteosynthesis and after removal of the Smith-Petersen nails



Figure 2 Both hips of patient B successively after the accident after osteosynthesis and after arthroplasty

The level of contrast medium extended to L1. The patient was then returned to his room and kept in a sitting position for 12 hours, whereupon he received a second dose of 20 mg Valium i.v.

About 4 to 5 hours after myelography he suddenly developed myoclonic spasms in both legs, followed by extreme flexion in both hips. Administration of 10 mg Valium i.v. reduced the myoclonic spasms. The next day he complained of bilateral inguinal pain, which seemed maximal during movements of the hip. A striking sign was lateral of both legs. X-ray examination of the pelvis revealed bilateral femoral neck fractures.

Reposition of the fractures was followed by fixation with Smith-Petersen nails. In the course of time the patient developed necrosis of the left and pseudarthrosis of the right hip, necessitating total hip arthroplasties (Figure 2).

DISCUSSION

Both case reports demonstrate that myoclonic spasms after myelography can lead to severe complications. In both cases bilateral femoral

neck fracture of the medial type (Gardner) was observed, leading to avascular necrosis and pseudarthrosis. In the literature there are six cases of fracture after myelography. In three patients the examination had been performed with Conray 60, and Dimer X had been used in the other three cases. In two cases fracture of the femoral neck was observed. In three cases, a unilateral fracture in the neck of the femur was observed. In one case fracture of the pelvis in one case.

Penning (1970) suggested that as a result of these myoclonic tonic spasms there should be sought in contact between the contrast medium and the conus medullaris causing irritation of the efferent system which regulates muscle tone. To avoid this contact it is advisable to have the patient in a straight position for 5 to 8 hours after the myelography. During this period there should be complete absorption of the contrast medium. It is also advisable to inject 10 ml of 1%

epam) i.v. before administering the opaque substance. Data from the literature show that of the above-mentioned six patients one was positioned horizontally two in a sitting position and three in an unspecified position after myelography. Only three of these patients received premedication before myelography; two patients received Valium and one was given phenobarbital. The literature offers the following advice for myelography:

1. Premedication with Valium i.v.
2. The quantity of radiopaque substance must not exceed 5 ml,
3. If possible, the radiopaque substance should not reach level L2-3.
4. For a period of 5-8 hours after the examination the patient should sit up straight.
5. In the case of excitation symptoms 1-40 mg Valium should be injected i.v.
6. The patient must be under observation for 24 hours.

DISCUSSION

It must be emphasized that the level attained by the radiopaque substance seems to be of great importance for the development of tonic spasms. When during myelography the radiopaque substance extends too far, contact between the conus and the cauda presumably occurs.

It is advisable to administer Valium prophylactically in a dose of 10 to 40 mg i.v.

even though Valium has not appeared to be 100 per cent effective. Lumbar puncture may also be considered in order to reduce the quantity of radiopaque substance used.

It should be noted that Conray 60 and Dimer X are no longer used for myelography in our hospital. We are currently using metrizamide (Amipac) which reportedly has a lower incidence of neurotoxicity. Time will tell.

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MECHANICAL STRENGTH OF SLIDING SCREW-PLATE HIP IMPLANTS

Biomechanical Study of Unstable Trochanteric Fractures. VI

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Static load testing of sliding screw-plate hip implants manufactured from
Cobalt-Chromium-Molybdenum alloy and 316 LVM stainless steel was
performed. The implants were tested in two positions, i.e. in the
anatomical position and in the position of maximum flexion. The
Jewett hip implants superior yield loads were determined for both implant
angles.

Calculations were made of the improvement of implant strength due to
the use of the sliding screw-plate system.

Key words: biomechanics, femoral neck fractures, fracture fixation, stress, mechanical.

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In recent years numerous papers have recommended the sliding screw-plate for internal fixation of unstable trochanteric fractures, as the number of technical failures has been reduced considerably with the use of this method in spite of a policy of early mobilization with full weight bearing (Ecker et al 1975, Jacobs et al 1976, Jensen et al 1978, Holland et al 1972, Parker & Reitman 1976).

In recently published studies the author analysed the modes of failure of Jewett and McLaughlin hip implants manufactured from Cobalt-Chromium-Molybdenum alloy or 316 LVM stainless steel (Jensen 1980) and focused on the failure loads, which were found to be less than the hip joint load during one-legged stance or normal level walking.

The purpose of the present study was to perform a comparable analysis of sliding screw-plate hip implants manufactured from the same metals and compare the results with those obtained in the former series (Jensen 1980 a b).

MATERIALS AND METHODS

The experiments were performed on sliding screw-plates manufactured from Cobalt-Chromium-Molybdenum alloy (Catalogue numbers 6447 6449-5-XXX, Howmedica Inc) or from 316 LVM stainless steel (Catalogue numbers 1131-01,02-XX, Zimmer-USA International) as shown in Figure 1.

In order to achieve results which can be compared with those of former series (Jensen 1980 a b) the moment arm about the intersection



Figure 1 Sliding screw-plate implants manufactured from Cobalt-Chromium-Molybdenum alloy (left) or 316 LVM stainless steel (right)

between the back of the plate and the centre line of the screw was kept at 41.4 mm corresponding to a screw length of 74.0 mm in implants with a 135° angle and to 127.0 mm in the 150° implants. Five experiments were performed for each series of 135° implants with 2.5" screws and 150° implants with 4.5" screws mounted in 3-hole plates.

The telescoping effect of the implants was eliminated by gluing the screw to the barrel with a slightly expanding 2-component polyurethane glue (Foss Than 2K 2350, Sadofoss, Denmark), which did not apply any additional bending strength. During the assembling process care was taken to ensure that the screw length was exact.

The difference between the two types of implants, apart from the metal is that the screw manufactured from Cobalt-Chromium-Molybdenum alloy is hexagonal with a diameter of about 9 mm and the rotational stability of the implant is ensured by a stud on the lower medial part of the barrel. The screw in the 316 LVM stainless steel modification has a circular cross section measuring 9 mm and a distally placed, longitudinal slot fitting with a tap in the barrel for rotational stability.

Strain gauges (QFLA 3 TML, ITC) attached to the implants at three positions: screw 3 mm from the medial edge of the barrel, the barrel 20 mm from the lateral border of the plate just distal to the corner-barrel for operation tools.

Static mechanical load testing was performed on the implants mounted in an interface to the vertical with simultaneous reaction applied load, the deflection of the axis, elongation of the moment arm and the strain as measured by the above-mentioned gauges.

A detailed description of the experimental arrangement has been presented in a paper (Jensen 1980a). Also included in previous publication are equations for the calculation (a) of the bending moments about the gauge centre on the screw and the barrel of the varus angulation of the implants.

The yield points, where the metal enters permanent plastic deformation, were marked as the points on the graphs where the straight line is transformed into a curved line.

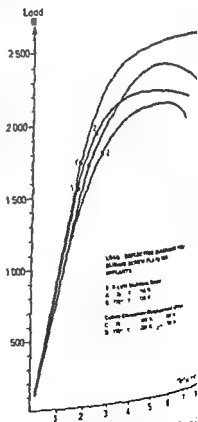


Figure 2 Load deflection diagrams for sliding screw-plate hip implants

RESULTS

load deflection diagrams for the sliding screw-plate hip implants are demonstrated in Figures 3 and 4. It is seen that two yield points were determined in implants manufactured from the Cobalt-Chromium Molybdenum alloy while the 316 LVM stainless steel implants exhibited only one yield point.

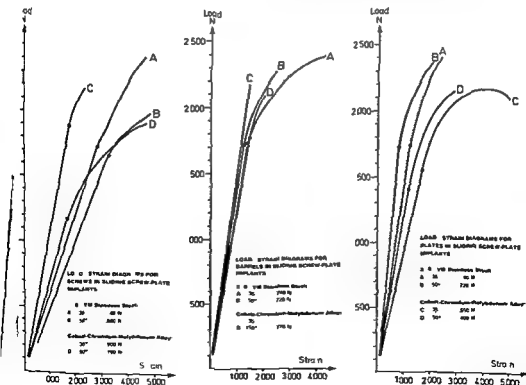
Figures 3, 4 and 5 show the load-strain diagrams for the screws, the barrels and the plates. They are demonstrated.

It was found that the single yield point determined for the 316 LVM stainless steel implants corresponded to a permanent plastic deformation arising simultaneously for all components of the implant. The yield load was found to be 1740 N for the 135° screw-plate and 1720 N for the 150° screw-plate.

For the Cobalt-Chromium Molybdenum alloy implants bending of the screw was observed at 1930 N in the 135° implant corresponding to the highest yield point while the plate bent at a load of 1550 N and the barrel did not show any sign of bending. Correspondingly the screw and the plate of the 150° implants bent simultaneously at a load of 1220 N while the barrel bent at a load of 1790 N. Bending of the screw was with both implant angles encountered at surface strains of about $1750 \mu\epsilon$ while bending of the plate was encountered at the level of the supporting steel bar 25 mm distal to the intersection between the centre line of the screw and the back of the plate.

For both types of metals the implants with a 135° angle were the strongest.

The varus angulation of the implants at the yield points encountered are listed in Table 1.



Figures 3, 4 and 5 Load strain diagrams for screws, barrels and plates of sliding screw-plate hip implants

Table 1 Calculations of the varus angulation in hip implants during mechanical locking

Screw-plate angle degrees	β degrees	Deflection e_1 mm	β_1 degrees	Varus angulation $\beta - \beta_1$	Deflection e_2 mm	β_2 degrees	Varus angulation $\beta - \beta_2$
135° - Co-Cr-Mo	56°	1.65	53.8°	2.2°	2.40	52.8°	1.2°
135° - 316 LVM	56°	1.85	53.5°	2.5°			
150° - Co-Cr-Mo	71°	1.50	69.0°	2.0°	2.75	67.5°	3.5°
150° - 316 LVM	71°	2.15	68.2°	2.8°			

$$\beta = \text{Nail plate angle} - 79^\circ$$

$$\sin \beta_x = \sin \beta - \frac{e}{L_N}$$

It is seen that varus angulations of about 2–3° corresponded to permanent deformations of the implants, as it has also been experienced with the Jewett and McLaughlin implants (Jensen 1980 a,b).

The bending moments about the strain gauge centre on the screws are listed in Table 2. It is demonstrated that the bending moments applied for bending of the screw were higher for 135° implants made from Cobalt-Chromium-Molybdenum alloy, where the highest bending moment applied to 150° implants was in the stainless steel modification. For the 135° implants the bending moments were thus 44–49 Nm, which is about double the 22–29 Nm for McLaughlin nail plates and about one third more than the strongest Cobalt-Chromium-Molybdenum alloy Jewett implants (Jensen 1980 a,b).

In the present series the telescoping of the sliding screw-plate implants is locked, and the holding capacity of the screw was not exceeded in any case. In the unscrewed situation, however, telescoping of the implants is experienced. Assuming the calculated bending moments always correspond to bending of the implants and similar varus angulation in the telescoping modifications, further calculations can be made on the effect of a telescoping of 10 and 20 mm, respectively, as listed in Table 3. It is thus seen that a telescoping of 10 mm improves the actual strength of the screw by about 28 per cent in the 135° implants and by about 11 per cent in the 150° implants compared with the telescoping of 0 mm. A telescoping of 20 mm improves the load bearing capacity of the 135° implants

Table 2 Calculated bending moments about the strain gauge centre on the screws in hip implants

Screw-plate angle degrees	Elongation of moment arm $\Delta M A$ mm	Reduction of moment arm X mm	Yield load J N	Bending moment M_B Nm
135° - Co-Cr-Mo	2.93	19.04	1,930	44
135° - 316 LVM	0.39	16.50	1,740	29
150° - Co-Cr-Mo	2.25	10.56	1,220	22
150° - 316 LVM	0.50	9.65	1,720	11

$$M_B = J \times (M A + \Delta M A - X)$$

X is calculated from the position of the intersection of the centre line of the screw and the nail plate in relation to the length of the barrel and $\alpha = 169^\circ - \text{screw-plate angle}$.

3 Calculations of yield loads of screw corresponding to reduced moment arms after telescoping of implants

plate	Bending moment about strain gauge	Telescoping = 10 mm		Telescoping = 20 mm	
		Moment arm ($L_N - 10$) sin α	Calculated load M_B	Moment arm ($L_N - 20$) sin α	Calculated load M_B
			$MA_1 + \Delta MA - X$		$MA_1 + \Delta MA - X$
		Nm	N	mm	N
- Co-Cr Mo	48.7	35.8	2,479	30.2	3,464
- 316 LVM	43.9	35.8	2,235	30.2	3,124
- Co-Cr Mo	40.3	38.1	1,354	34.8	1,519
- 316 LVM	55.4	38.1	1,914	34.8	2,156

80 per cent and the 150° implants by 25 per cent. The yield loads thus obtained for the 135° implants correspond to 4.1 times the body weight of a 60 kg man after a telescoping of 10 mm and to 8 times the body weight after a telescoping of 20 mm.

DISCUSSION

Recent types of sliding implants have been focused for the treatment of hip fractures (Sie 1962, 1964, Pugh 1955, Schumpelich 1955), but the most widely used telescoping implant in Western Europe is the sliding screw-plate, originally described by Jørgensen (1964) and subsequently proven to be mechanically efficient. Hence it was decided to perform biomechanical studies on this type of implant, made of Cobalt-Chromium-Molybdenum alloy or 316 LVM stainless steel.

The results could be compared with those obtained with Jewett and McLaughlin implants tested previously (Jensen 1980 a, b).

According to Jørgensen (1964) internal fixation of fractures always implies very small movements at the fracture site, which might cause any macroscopic displacement but lead to fatigue fracture of the implant (Jørgensen et al 1977). In the case of unstable trochanteric fractures the mechanical weight transmission over the fracture site is unstable, because an exact reduction of the

fracture can not be obtained (Clawson 1957, Johnston 1973, Kennedy et al 1957, Kumar 1973). This leads to repeated, high stresses on the implant and may give rise to fatigue fracture of the implants, it also involves a risk of implant breakage following sudden stress of high magnitude (Bechtol & Murphy 1952).

Biomechanical studies of sliding screw-plates have been performed on a model of unstable, 4-fragmentary trochanteric fractures with different modifications of reduction and fixation by hip implants (Kaufer et al 1974, Sonstegard et al 1974). In these experiments, however, the possible movement of the implant within the femoral head as well as the holding power of the screws in the femoral shaft could not be considered and consequently only the ultimate compressive strength of the implants was reported. It is, however, more important to define the yield point where permanent plastic deformation begins, as considerable bending can take place before the ultimate strength of the implant is exceeded (Brettle et al 1971, Dumbleton & Black 1977) and thereby result in dislocation of an internally fixed fracture.

Compared with the studies mentioned (Kaufer et al 1974, Sonstegard et al 1974) however, the results obtained in the present series were quite similar for stainless steel implants with a 135° angle.

In the 316 LVM stainless steel implants all three parts of the implant, i.e. the screw, barrel and plate bent simultaneously at loads

of about 2.9 times the body weight of a 60 kg person. This means that the implants can accurately resist the lowest hip joint load during level walking, as reported by Paul (1976) and Rydell (1966), and are thus found to be suitable for the internal fixation of unstable trochanteric fractures where no reliable bony support is obtained. The internal fixation of these fractures does, however, not only concern the mechanical strength of the implant but also the degree of osteoporosis of the femoral neck and head. A high strength implant may lead to an increased number of cuttings or penetrations through the mechanically weak bone. The main advantage of the sliding implants is the ability of the screw to telescope when the fractured bone ends tend to impact as a result of muscular tension and weight-bearing. Thus a stable load transmission system is created through bony contact. The telescoping of the screw not only prevents perforation of the bone, but also improves the weight bearing capacity of the implant by a reduction of the moment arm. For the 135° implants manufactured from either of the metals a telescoping of 10 mm thus increased the weight-bearing capacity to 3.7–4.1 times the body weight of a 60 kg person and a telescoping of 20 mm to 5.2–5.8 times the body weight, which is above the hip joint load calculated for normal level walking.

In the tests on the implants manufactured from Cobalt-Chromium-Molybdenum alloy two yield points were encountered. For the 135° implant the lowest yield point in the experiments was caused by bending of the plate at the level of the supporting steel bar. In a clinical situation, however, the plate is supported by cortical bone up to the junction with the screw and thus yield point is therefore considered of less importance. The 135° implant is thus strong enough for the internal fixation of unstable trochanteric fractures. The lowest yield point in the 150° implants is, however, caused by bending of not only the plate, but also the screw at loads of about 1,220 N, which is comparable with the results obtained at mechanical testing of

125° and 135° Jewett hip nail-plates (Jensen 1980a). The yield loads presented here are equal about twice the body weight of a person and consequently can be recommended for the internal fixation of unstable trochanteric fractures following early weight bearing mobilization. Telescoping of 10 or 20 mm respectively improves the weight bearing capacity of a sliding screw plate implant by 11 and 5 per cent, but it is still less than 2.5 times body weight. As seen from the results, even the 150° sliding screw plate implant manufactured from 316 LVM stainless steel is of doubtful reliability. It does not improve the weight bearing capacity more than only 3.2–3.6 times the body weight.

However, compared with the results obtained at the mechanical testing of the Jewett and McLaughlin implants (Jensen 1980b), the sliding screw plate implants are clearly superior and should be recommended for the fixation of unstable trochanteric fractures, although the best solution from a mechanical point of view is a nail-plate made from either of the metals for this purpose.

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ECTOPIC BONE FORMATION FOLLOWING CHARNLEY HIP ARTHROPLASTY

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In a consecutive series of 309 patients the degree of ectopic bone formation was assessed 3 months, 2 years, and 5 years after total hip arthroplasty. At the three follow-up examinations ectopic bone formation was found in 49 per cent, 61 per cent, and 71 per cent. In men ectopic bone formation was more common and more pronounced than in women. It was demonstrated that walking ability and range of hip movement may be reduced in the presence of ectopic bone formation. A past history of hip surgery, preoperative exostoses, and postoperative elevation of the erythrocyte sedimentation rate did not appear to influence the formation of ectopic bone. There was no correlation between the degree of ectopic bone

postoperatively

Key words: ectopic bone formation, total hip arthroplasty

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Ectopic bone formation (EBF) is a common occurrence after arthroplastic operations on the hip. Its cause is unknown. It is known to be an intramembranous ossification (Nollen 1973, Rosendahl et al 1977). Nollen, in 1973, demonstrated that the concentration of alkaline phosphatases rose to significantly higher values in patients who developed EBF postoperatively than in those who did not. In the literature it is agreed that it is not possible to point out preoperative factors which may lead to postoperative EBF. On the other hand, opinions differ as to the clinical significance of EBF.

This paper reports a clinical study. A number of clinical characteristics of EBF in a consecutive series of 309 patients will be

described, and in the discussion the results will be compared with those of others.

PATIENTS AND METHOD

The patient material comprises the first 309 patients who underwent hip replacement by the method of Charnley in the Department of Orthopaedic Surgery O, Odense University Hospital. Their median age was 61 years, range 26-78 years, 138 of the patients were males and 171 females. Bilateral operation was performed in 56 cases. All the patients were operated on according to the method of Charnley, with the lateral approach to the hip joint, trochanteric osteotomy, and total excision of the hip joint capsule. After insertion of the prosthesis the trochanter was reattached using cerclage wires of stainless steel.

The patients were seen at follow-up 3 months, 2 years, and 5 years after the operation. From these examinations 356, 320, and 138 X-ray films were available for use in the present study. The EBF was measured on routine anteroposterior views.

EBF was graded according to the classification used by DeLee et al. (1973), which ranges from no EBF to bridging EBF (Table 1). For the clinical assessment of hip function we used Charnley's (1972) grading for hip pain, walking ability, and range of hip motion with a score from 1 to 6. With this grading, 6 signifies a normal hip and 1 a hip with constant pain and disablement. For groups of patients these scores are given with 1 decimal place.

Table 1 Grading of ectopic bone formation

Grade 0	No ectopic bone
Grade 1	Ectopic bone less than 50 per cent of the distance between the femur and pelvis.
Grade 2	Ectopic bone 50-99 per cent of the distance between the femur and pelvis.
Grade 3	Ectopic bone bridging the distance between the femur and pelvis.

RESULTS

Table 2 gives the incidence and sex ratio for EBF. At 3 months, 2 years, and 5 years, EBF was present in 49 per cent, 61 per cent, and

71 per cent, respectively. There were 53 males and 53 females. The incidence of EBF was 45 per cent and 65 per cent. At 3 months 49 per cent of the patients had bridging EBF. With increasing frequency, over a 5-year period increasing EBF was found. It was apparent from the study that men had grades of EBF more often than women. At 2 years the difference between men and women with and without EBF was statistically significant ($P < 0.05$). At 5 years the incidence of bridging EBF was twice as often as without. The influence of EBF upon the clinical results in terms of pain, walking ability and range of hip motion - is shown in Table 3. As to the above-mentioned function, there were no convincing differences between the grades of EBF. On the other hand, walking ability and range of hip motion showed, at 2 years and 5 years, a reduction of function which was directly proportional to the severity of EBF. If the patients had EBF (grades 2 and 3) there was a statistically significant ($P < 0.05$) reduction of walking ability and range of hip motion at 2 years.

Among the 45 bilaterally operated patients there was at 2 years the following difference between the grade of EBF in the

Table 2 Frequency of ectopic bone formation and sex ratio of patients with this complication

	Ectopic bone formation (grade)					
	0		1		2	
	No.	Per cent	No.	Per cent	No.	Per cent
At 3 months						
Total number	183	51	113	32	41	12
Males	80	47	60	36	19	11
Females	103	55	53	28	22	12
At 2 years						
Total number	123	39	110	34	61	19
Males	47	31	60	40	29	20
Females	76	45	50	30	32	19
At 5 years						
Total number	40	29	51	37	34	25
Males	18	24	29	39	19	25
Females	22	35	22	35	15	24

4) The same grade in 19 cases (42 per cent), a difference of more than 1 grade in 9 cases (20 per cent), and in 16 patients (36 per cent) there was no EBF in one hip, but 1 or 2 in the other.

After hip surgery had been performed on patients prior to the arthroplasty. At 2 years the EBF findings were grade 0, 1, 2, 3 in 23, 17, 6, and 4 patients, or 46 per cent, 34 per cent, 12 per cent, and 8 per cent of the total material, this group of patients showed no increase in EBF.

In the preoperative X-ray films the exostoses were measured at the upper lateral of the acetabulum, and the findings were divided into four groups according to the length of the exostoses in millimetres. Table 5 shows the relationship between exostotic size and the grade of EBF at 2 years after operation. For exostoses ≤ 20 mm the findings in the groups correspond to those in the total series. Only 16 patients had exostoses exceeding 20 mm in length. It may

be mentioned that none of these patients with large exostoses developed bridging EBF postoperatively.

Finally, it was investigated whether an elevated erythrocyte sedimentation rate was demonstrable at 3 months in patients who developed EBF. Table 6 shows there was no such correlation. On the contrary, among 41 patients with an erythrocyte sedimentation rate > 30 mm/h, 20 patients had no EBF, 10 patients grade 1, one patient grade 2, and one patient grade 3 EBF.

DISCUSSION

EBF develops rapidly, often within 1 month (Nollen 1973, Spranger 1973). Of our patients 49 per cent had developed EBF 3 months after the operation. DeLee et al (1973) and Spranger (1973) have reported that the condition remains stationary after 1 year. Unlike them we found an increasing

Table 3 Clinical evaluation in cases with ectopic bone formation

	Ectopic bone formation (grade)			
	0	1	2	3
<i>At 2 years</i>				
Pain	5.5	5.7	5.8	5.4
Walking ability	5.3	5.0	5.1	4.5
Range of motion	4.8	4.6	4.3	3.8
<i>At 5 years</i>				
Pain	5.4	5.5	5.3	5.7
Walking ability	5.4	5.0	4.9	4.9
Range of motion	4.8	4.7	4.2	4.0

Table 4 Ectopic bone formation in bilaterally operated patients (at 2 years after the operation)

	Ectopic bone formation (grade) left hip			
	0	1	2	3
	0	8	3	3
Ectopic bone formation (grade) right hip	1	5	7	2
	2	5	6	1
	3		1	3

Table 5 Preoperative presence of exostoses and postoperative ectopic bone formation (at 2 years after the operation)

Exostosis (mm)	Ectopic bone formation (grade)							
	0		1		2		3	
	No	Per cent	No	Per cent	No	Per cent	No	Per cent
0	42	43	29	30	16	11	10	10
1-10	55	37	52	35	30	20	11	11
11-20	24	41	19	32	11	19	5	5
> 20	2	13	10	62	4	25	0	0

Table 6 Ectopic bone formation and the erythrocyte sedimentation rate (at 3 months after the operation) 345 patients

ESR (mm/1 h)	Ectopic bone formation (grade)			
	0	1	2	3
0-20	127	87	33	14
21-30	24	10	6	3
31-40	10	6	1	
41-50	12	2		1
> 50	7	2		

frequency and severity up to 5 years after the operation, in particular for grade 2. The total frequency of EBF in our material was relatively high. Charnley (1972) reported 5 per cent, Lazansky (1973) 8.1 per cent, Bergstrom et al (1973) 19 per cent, and Spranger (1973) 25 per cent. Rosendahl et al (1977) found a much higher frequency (90 per cent). Reports in the literature that men are more apt than women to develop EBF (DeLee et al 1973, Lazansky 1973) were confirmed by our findings as early as at 3 months after the operation, and at 5 years bridging EBF was present in twice as many men as women.

There is no agreement concerning the clinical significance of EBF. Charnley (1972) and Bergstrom et al (1973) reported that on the whole it had no influence upon the result. Johnston (1973) reported that EBF rarely caused poor results. On the other hand, Ilstrup et al (1973) found that pronounced EBF significantly reduced hip function, and

this view was supported by Rosendahl (1977). According to DeLee et al it was impossible to predict the result in patients with only slight EBF. In patients with reduced hip function, while in patients with severe EBF hip function might be reduced. This latter observation is no doubt true in some cases. Our total results support the view that EBF does not give rise to pain, but that it may reduce the ability and the range of hip motion. This reduction is directly proportional to the degree of EBF.

Among bilaterally operated patients we found no convincing correlation between the degree of EBF in the two hips. Unlike DeLee et al (1973) therefore, we believe that there is no evidence of uniform development in the two hips. Our findings indicate that EBF is indeed our findings indicate that EBF is a constitutionally governed phenomenon. Our values show that patients with a high degree of EBF are not a high risk group as regards the development of EBF. This was also pointed out by Ilstrup et al (1973).

Lazansky (1973) stated that the degree of preoperative exostoses the best predictor of EBF, while DeLee et al (1973) stated that the formation of EBF was unrelated to the size of the osteophytes as well as to the possible removal at operation. In our material there was nothing to indicate that the exostoses could be used to predict the degree of EBF.

An elevated erythrocyte sedimentation

the arthroplastic operation is, according to Ilan (1973), not typical of patients who are going to develop EBF, and thus they took support the view that EBF is not an inflammatory process. We agree with this. In the present material 76 per cent of patients had an erythrocyte sedimentation rate ≤ 20 mm/1 h (normal value), and apart from 2 patients all those who had an erythrocyte sedimentation rate > 30 mm/1 h had EBF of grade 0 or 1.

In the present study it was not possible to stratify groups of patients with an increased risk of developing EBF after arthroplastic operation on the hip.

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REPLACEMENT WITH THE McKEE-FARRAR STHESIS IN RHEUMATOID ARTHRITIS

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A follow up investigation was made of 78 patients suffering from rheumatoid arthritis (RA) who underwent total hip replacement (THR) according to McKee-Farrar during the years 1969-1975. There were 27 bilateral cases. The mean observation time was 47 months (range 9-85 months)

performed on the 78 patients. No correlation was shown between the results and RA serology, age at THR, preoperative classification of hip radiographs, or observation time. A high frequency of migration of the prosthetic components was found.

Key words: arthritis, rheumatoid arthroplasty, hip

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ly reports on total hip replacement (THR) include patients treated for rheumatoid arthritis (RA). Comparison of the results is usually difficult and often impossible as the criteria for assessment of results are not standardized. Andersson (1972) evaluated and assessed the results of Moore arthroplasty in a group of patients according to three different assessment methods at the same time and found great discrepancy between the results. According to the method used, the percentage of good results varied from 30 to 97 and the poor results varied from zero to 48 per cent. Another cause of difficulties is that the results in published series seldom are stratified according to the different prognostic categories of the patients. The problems of the RA patient needing THR

differ in many ways from the problems of a patient with osteoarthritis or ankylosing spondylitis (Baldursson et al 1977).

Table 1 lists some reports of THR in RA in which the parameters of pain, walking ability and hip mobility are reported in a manner that allows comparison of results. Good pain relief and increased hip mobility are constant findings in the reports, but walking ability is not consistently improved.

Rheumatoid arthritis is a chronic disease with periods of exacerbations and remissions. Fluctuations in disease activity make evaluation of results difficult. Often there are symptoms arising from many joints and multiple operations may be needed. The patients are often relatively young. The patients are perhaps unable to use walking aids because of hand or arm impairment. The

Table 1 Some earlier reports on total hip replacement in rheumatoid arthritis

Year	Author	Reviewed		Mean age (years)	Observation time (months)	Results		
		Pat	Hips			Pain relief	Walking	Stair
1970	Welch & Charnley	186	274	54	> 12	Grade 5 or 6 in 99 per cent*	Small improvement	Varies
1972	Arden et al	27	40		Min 12	No pain or occasional discomfort in 90 per cent	Improved	24 to 26 per cent
1972	Harris et al		46		Min 3	No pain or occasional discomfort in 79 per cent	Not evaluated	26 to 28 per cent
1973	Bucholtz & Noack	296	403		Min 24 for 169 patients	Mean grade 5.6 after THR*	Mean grade increased from 2.0 to 4.4*	Varies
1974	Deutman	22	27		Min 12	Grade 5 or 6 in 96 per cent*	Mean grade increased from 1.3 to 3.0*	Varies
1975	Halley & Charnley	21	38	All < 30	Mean 37.6 (6-99)	97 per cent pain-free*	Mean grade increased from 2.0 to 3.6*	Varies
1976	Posset al	205	275	55	Min 18	Relief in 96 per cent	Improved in 82 per cent	Improved
1978	Colville & Raunio	278	378	39	Mean 30 Min 12	Grade 5 or 6 in 95 per cent*	Not evaluated	Varies

* Grading according to the method of d'Aubigné & Postel (1954)

osteoporotic bone in RA causes special technical problems during operation

Total hip replacement has been performed in our department since 1969. Initially, the McKee-Farrar prosthesis was chosen as the standard type for RA patients. The use of all-metal prostheses has later been discontinued, the last McKee-Farrar hip was inserted in 1975. A change to metal-plastic prostheses was made because of reports of high friction and wear in all-metal hip prostheses (Swanson et al 1973). The high friction combined with low elasticity in the metal socket puts greater strain upon the cement-bone interface in an all-metal hip than in a metal-plastic hip prosthesis. This probably increases the risk of loosening, particularly with the abnormally soft bone often found in RA.

Animal experiments suggest (Faral 1973) that wear particles from chromium-molybdenum prostheses are capable of inducing osteolysis. Furthermore, metal sensitivity to wear particles, has been suggested as a possible cause of prosthesis loosening (Evans et al (1974) and by Jones et al). The purpose of this study was to evaluate the complications and results of a series of RA patients operated on with McKee-Farrar hip prostheses.

PATIENTS AND METHODS

A follow-up investigation was made of 20 patients with definite or classical RA and of 20 McKee-Farrar prostheses in the femur.

opaedic Surgery of the University Hospital of during the years 1969 to 1975. Before the beginning of this study, in 1974, seven patients died of causes unrelated to the THR. All who were alive at that time were examined by the author at least once (Table 2). The mean age at THR was 56 years (20-75 years), the mean duration of RA at THR was 18 years (2-47 years) and the mean duration of hip symptoms was 6 years (6 months-27 years). Twenty patients had a seropositive RA. The conditions immediately before THR were compared with the conditions at the last follow-up examination. In eight hips in which the prosthesis had been removed, exchanged or reinserted, the conditions immediately before the reoperation were taken as the last follow-up examination. Pain, walking ability and hip mobility were graded according to the method of d'Aubigné & El (1954) in the form used by Halley & Finley (1975) except that alphabetic prefixes were not used. This method assessed hip mobility as the sum of flexion, extension, abduction, adduction, internal rotation and external rotation. The main indication for THR was pain in 99 hips and stiffness in six. Pain of grades 1-3 according to the grading system of d'Aubigné & El (1954) was present before THR in 102 hips. Hip mobility of grades 1 or 2 according to the same system was found in 25 hips. Observation time was defined as the time from THR to the last follow-up examination or removal, exchange or reinsertion of the original McKee-Farrar prosthesis. One exception was made. This hip was unstable after THR and it was decided to reoperate after the operation and had healed. The prosthesis was exchanged 2 years after the primary THR. In this one case, the second prosthesis was regarded as primary and the first one was excluded from the assessment of results. The mean observation time was 47 months (9-85 months). For 101 THRs, the observation time was 24 months or longer. Three

prostheses had been removed within 24 months after THR and one patient in this series died 22 months after THR.

Fifteen of the 105 operated hips in this material had been operated on prior to THR. Cup arthroplasty had been done in seven hips, synovectomy in five, and nailing of a pertrochanteric fracture in one. In one hip an osteotomy of the proximal femur had been done and in another, an arthrodesis followed by an osteotomy of the proximal femur.

As a part of the rehabilitation of the patients, in addition to the McKee-Farrar hip prostheses, 332 other orthopaedic operations were performed, 217 of these were done before THR (Baldursson & Brattstrom 1979b).

All radiographs were examined by a radiologist (Tord H. Olsson) and special attention was paid to migration of prosthetic components.

The preoperative radiographs were graded (by the author) according to the method of Larsen et al (1977). Fourteen hips had medium destructive changes with erosion and joint space narrowing (Grade III). Twenty-one hips had severe destructive changes with bone deformation in addition to erosion and joint space narrowing (Grade IV). Sixty-two hips had mutilating changes with disappearance of the original articular surfaces and gross bone deformation (Grade V). In eight hips the grading method was not applicable because of previous operations.

General anaesthesia was used in all cases. Antibiotic prophylaxis with penicillin or cloxacillin was started before operation in 44 THRs, and in 43 antibiotics were only given postoperatively. This prophylaxis was usually given for 2 weeks. In 11 THRs, no antibiotics were given. All THRs were carried out in a conventional operating room. This room was only used for clean orthopaedic surgery, and the THRs were done as the first operation in the morning. No bilateral THRs were done in one session.

The standard approach to the hip was through an anterolateral incision. The technique of McKee & Farrar (1966) was used, except that it was rarely considered necessary to place the patient on an extension table. Because of the risk of fracturing the femur, the femoral neck was usually divided *in situ* instead of dislocating the hip. One or two suction drains were put in the wound through separate incisions.

Radio-opaque bone cement was used in 87 THRs. The cement was pressed into the femur with plastic rods or with the fingers. Antibiotic-containing cement was not used. The femoral part of the prosthesis was usually reduced into the socket before the cement in the femur had hardened.

Table 2 Patients

	Patients	THRs
Operated 1969-1975	85	112
Excluded before the beginning of this study	7	7
Unstable for study	8 patients	105 THRs
Examined		
Men	71	29
Women	47	76
Total	118 patients	105 THRs

The mean operating time was 150 minutes (75-230 minutes)

There was no mortality in connection with the primary THRs

first on the day after THR. Recovery has been only partial

One supracondylar fracture of the femur occurred during THR. It was treated by skeletal traction and healed uneventfully. In five THRs the reamer perforated the femur, but this was seen during the operation and a new reaming was done. No harmful effects of these perforations have been seen.

In another five THRs perforation also occurred but was not detected until postoperative radiographs had been taken and the tip of the prosthesis was seen to protrude from the femur. Two of these prostheses (in the same patient) have loosened and been removed. In one case after a failed exchange of a prosthesis. The other three THRs have functioned well without visible ill effects of the protruding stems (observation time 66-84 months).

In one hip a lump of cement on the ventral side of the hip joint was thought to hinder hip flexion and was removed surgically 3 months after THR.

One hip mentioned above dislocated on the day after THR and could not be kept from dislocating again except by abducting and internally rotating the hip. Two weeks after the primary THR the prosthesis was exchanged and the hip functioned well after that.

Superficial infection was noted after nine THRs, none of which had proven or suspected deep infection. In four of these, antibiotics had been given before and after THR. In two hips antibiotics were given only after THR. In one hip antibiotic prophylaxis was started before THR but by mistake the patient then had no antibiotics for the next 24 hours. In two THRs no antibiotic prophylaxis was given.

Deep infection was considered proven in two THRs with positive bacteriological culture. In one of these no antibiotic prophylaxis had been given. In the other THR cloxacillin had been given only postoperatively. One of the infected THRs has been exchanged but in the other the patient's general condition contraindicated exchange of the prosthesis.

In one hip deep infection was suspected on clinical and radiological grounds. Samples were taken for aerobic and anaerobic bacteriological cultures from the medullary canal of the femur. The cultures were negative but the patient died suddenly 2 days after the exploratory operation.

At the autopsy both parts of the prosthesis were loose from the bone.

Fracture of the acetabulum after THR was found in four hips 15 months after THR. Three of these had a small acetabular protrusion of 3 mm or less. Two prostheses were removed because of pain and new prostheses were inserted. The other patients with acetabular fracture have been re-operated and are able to walk distances with calipers to take the weight of the hip.

Prosthetic exchange was performed in four hips because of pain and loosening of the prosthesis. Infection has not been proven in these hips.

One socket loosened suddenly 6 weeks after THR and the patient was re-operated in hospital with reinsertion of the new prosthesis. Infection was not found.

RESULTS

Table 3 demonstrates that three hips were pain free before THR. Two of them were ankylosed and the third had only limited mobility. Following THR, 99 hips were pain free, five were unchanged and one was more painful than before THR.

The mean pain grade before THR was 2.5 and at follow up 5.5. Eleven hips had a pain grade of three or lower at the last examination. In ten cases, the pain was considered to be due to loss of stability caused by mechanical loosening of the prosthesis.

Table 3 Pain assessed according to the method of Aubigné and Perle

Before THR							
Grade	1	2	3	4	5	6	Total
6	45	16	18			3	82
5	3	1	2				6
4	3	1	1				5
3	7	1	1				9
2							0
1	1	1					2
	60	20	22			3	105

1 Walking ability assessed according to the method of d'Aubigné and Postel

Before THR (Before 1st THR in b lateral cases)

	1	2	3	4	5	6	
	1	3					4
	1	2	1	1			5
	7	13	2				24
	11	14	1	1			27
	14	3	1				18
	34	35	7	2			Total

As follow-up

ular fracture. In one hip, the cause of an could not be explained.

ble 4 shows that following THR the ng ability increased in 39 patients, ined unchanged in 33 and diminished in The mean grade for walking ability was before THR and 2.4 at follow-up.

ible 5 shows that following THR, lity improved in 86 hips, remained aged in 15 and diminished in four. The 1 grade for mobility before THR was 3.2. At follow-up 4.6. At the last follow-up ex- ation, the total range of motion was less 100 degrees in five hips. Two of these were evaluated immediately before re- ation, another belongs to a patient who is ichair-bound because of a cerebral

5 Hip mobility assessed according to the method of d'Aubigné and Postel

	Before THR						
	1	2	3	4	5	6	
6		3	4	5	3		15
5	8	2	9	23	3		45
4	2	7	18	17	2		40
3	1		1				2
2	1						1
1		1	1				2
	12	13	33	39	8		Total

As follow-up

haemorrhage and the last two were ankylosed before THR.

Table 6 shows that before THR there was severe pain or stiffness in all 105 hips. Considerable pain as well as stiffness was found at follow-up in two hips, nine had pain, but mobility was fair. There was one painless stiff hip.

The functional capacity was assessed according to the criteria of the American Rheumatism Association (Steinbrocker et al 1949). Eighteen patients were considered improved, 48 unchanged and 12 worse at follow-up than before THR (Baldursson & Brattstrom 1979a).

Sixty-one patients with 87 THRs in whom the original McKee-Farrar prosthesis was in place were examined at least twice with at least a 12-month interval between the examinations and with at least 12 months between THR and the first examination. This was carried out to see if there was any change in the results between the examinations. The mean time from THR to the first examination was 30 months and the mean time between the two examinations was 21 months. Of the 18 hips not included in this group, eight were failures (see below). The pain grade was unchanged between the first and the last examination in 77 hips, four were improved and six were worse. Mobility was unchanged in 62 hips, improved in eight and worse in 17. Most of the variations amount to only one grade according to the system of d'Aubigné & Postel.

Pain relief and increase in mobility after THR were further analysed in relation to 1)

Table 6 Pain and stiffness before and after THR

	P	P+S	N
Before THR	80	11	3
At follow-up	9	2	1

P = pain, i.e. grade 1-3 according to the grading method of d'Aubigné & Postel.

S = stiffness, i.e. mobility grade 1 or 2.

'ATERAL PERTHES' DISEASE

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Bilateral Perthes' disease is defined as the form of the condition where radiological changes affect both hips simultaneously. The radiological abnormalities are symmetrical or asymmetrical.

Key words: Perthes' disease, bilateral disease, simultaneous radiological changes, two unilateral attacks

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occasional bilateral occurrence of Perthes' disease has been known since Calvé's (1900) and Perthes' (1910, 1913) classic papers. Although the existence of bilateral disease has been doubted, no detailed study of this form of Perthes' disease has been published. The relative incidence of bilateral disease has varied widely in the larger series reported. Sander (1965) found that only 7 per cent of his patients with Perthes' disease had bilateral involvement, although Lauritzen (1975) recorded a 22 per cent relative incidence. This difference might have arisen because the criteria for bilateral disease have not been fully formulated. Radiological abnormalities in the affected hip in unilateral disease have been observed and recorded many times over years (Sandoz 1928) and these changes have been held to be an abortive form of Perthes' disease by most authors. This paper reports the study of the radiographs of 147 patients with Perthes' disease. An attempt is made to define bilateral Perthes' disease to differentiate it from unilateral disease and from what can be regarded as unilateral disease affecting the hips at grossly different ages.

RADIOLOGICAL STUDY

About a third of all the patients who had been treated for Perthes' disease in Leeds, Bradford and Nottingham between 1944 and 1978 had surviving 'full sets' of radiographs, taken at regular intervals from diagnosis to healing. Not all of them had lateral views taken. The affected side(s) and the severity of the disorder - whether or not fragmentation of the femoral capital epiphysis occurred - could, however, be assessed. A total of 147 sets of radiographs were available to the author comprising a random selection of the

1 Fragmenting type of Perthes' disease affecting both sides simultaneously and progressing concurrently

This type of the disease was rare: only two patients were found in this series. In both patients the symptoms referred to only one of the hips during the whole course of the disease. Figures 1 to 4 show radiographs of one of the patients with this type of Perthes' disease. This boy was treated on a Jones's abduction frame for a year, then he was mobilized in patten ended calipers. The radiological features of the disease in both these children were thought to be reminiscent of

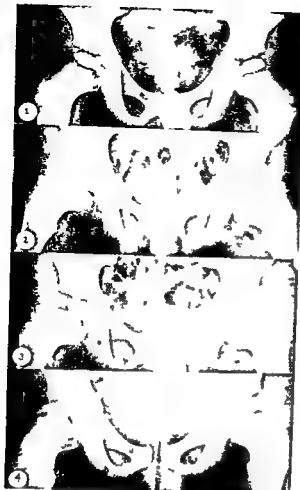


Figure 1 Radiograph of a boy who was 4 years old at the onset of right sided symptoms of Perthes' disease

Figure 2 Both femoral capital epiphyses begin to fragment 6 months later

Figure 3 Fragmentation continues 5 months later

Figure 4 Re constitution of the capital epiphyses 1 year later

multiple epiphyseal dysplasia'. Radiological surveys however failed to reveal abnormalities in other epiphyses.

II Perthes' disease affecting both sides simultaneously, but only one capital epiphysis showing fragmentation

Six patients showed this type of radiological appearance in this study. All had symptoms referable to only one of the hips during the whole course of the disease the symptoms were not always related to the hip which later developed fragmentation. Figures 5 to 7 show radiographs of



Figure 5 Radiograph of a boy who was 4 years old at the onset of right sided symptoms of Perthes' disease. He never had symptoms on the left

Figure 6 Twelve months later the right femoral capital epiphysis shows fragmentation

Figure 7 Eighteen months later the right femoral head is more rounded than the left

one of the patients with this type of Perthes' disease. This boy only had symptoms referable to his right hip where fragmentation had developed. As expected the hip which had fragmentation healed with a better rounded femoral head than the hip where the capital epiphyses showed fragmentation.

III Apparently unilateral Perthes' disease with radiological abnormalities on both 'uninvolved' hip also

Analysis of the radiographs of the patients in this series revealed abnormalities on the 'uninvolved' side of those patients who were thought to have unilateral disease. These abnormalities included (i) Irregularities in the contour outline of the femoral capital epiphysis. (ii) Flattening of the infero-medial part of the capital epiphysis. (iii) Positive Gale's sign (i.e. convexity of the upper border of the capital epiphysis) and (iv) Irregularities in the shape of the metaphysis.



Figure 8 Radiograph of a boy who was 3 years old at the onset of symptoms of Perthes' disease on the right side only. The right capital epiphysis is irregular in density and outline, Gage's sign (see text) is positive.

Figure 9 Two years later, healing Perthes' disease on the left, little evidence of abnormality on the right.

In every one of these 62 patients one or more of the following irregularities were observed in the involved hip. The patients' symptoms referred to the hip which showed typical Perthes' disease. Some 19 of the 62 patients did not show fragmentation of the capital femoral epiphysis.

The radiographs in figures 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62 show the radiological appearances found in the different types of Perthes' disease.

Unilateral Perthes' disease affecting first one hip and then after a clear time interval the other

In the patients in the study had this presentation. They represented the majority of those patients who had been designated as having 'bilateral' Perthes' disease. They all presented with what seemed to be unilateral disease, symptoms of which were relieved by treatment.

In the patients in the study had this presentation. They represented the majority of those patients who had been designated as having 'bilateral' Perthes' disease. They all presented with what seemed to be unilateral disease, symptoms of which were relieved by treatment. Figures 12 to 15 show a typical case of this type.

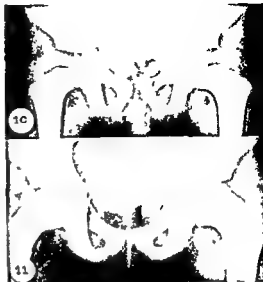


Figure 10 Radiograph of a boy who was 3 years old at the onset of left-sided symptoms of Perthes' disease. Typical changes on the left. The right capital epiphysis is irregular in density and outline, its infero-medial border is flattened, Gage's sign is positive.

Figure 11 Four years later, healed Perthes' disease on the left, apparently normal right hip.

of Perthes' disease in a girl who was 4 years old at the onset of left-sided disease. A year and a half later the right hip was affected.

V Unilateral Perthes' disease

The radiographs of 68 patients showed unilateral Perthes' disease only, with no radiological irregularities observable on the unaffected side. Their symptoms related only to the hip with Perthes' disease. The study of the radiographs of these patients were included in a series reported earlier (Nevens et al 1977).

DISCUSSION

Since the original description of Perthes' disease in 1910, little attention has been paid to the bilateral form of the disorder other than noting its existence. No clear definition of



Figure 12 Radiograph of a girl who was 4 years old when left sided Perthes' disease was diagnosed. Right hip clinically and radiologically normal.

Figure 13 One year later typical left Perthes' disease still no abnormality on the right.



Figure 14 Eight months later the symptoms on the right. The healing Perthes' disease on the left and fragmenting Perthes' disease on the right.

Figure 15 Three and a half years later Perthes' disease. The result is a normal right as expected.

bilateral disease has been established and this might explain why such dissimilar figures have been quoted for its relative frequency. Values for the relative frequency of bilateral Perthes' disease in the literature have ranged from 7 per cent (Wilk 1965) and 12 per cent (Edgren 1965) to 22 per cent (Lauritzen 1975). Ferguson (1975), however, was reluctant even to accept the concept of bilateral disease in any form.

Most authors who noted the occasional presence of radiological abnormalities on the symptomless side of unilateral Perthes' disease considered them to be due to 'abortive or fleeting' Perthes' disease (Sandoz 1928, Sundt 1949, Goff 1954, Katz 1965, Chivabongs 1972, Mattner & Tomaschewski 1975 and Kranitz et al 1976). Enr & Komprda (1968) felt that these abnormalities represented a 'developmental variation' rather than the disease process itself.

Until the aetiology and pathogenesis of Perthes' disease is known the assessment of

the condition will remain uncertain. Recent evidence (Nevels et al 1978, Burch & Nevels 1978) that Perthes' disease might be due to a process in the proximal femur of a more general disease process with a possible genetic basis. The finding of radiological changes in both hips at the same time supports this notion. Thus it is logical to consider three types of the disorder. In this paper to be manifestations of a radiological severity of Perthes' disease. The series of radiographs here was not an 'inclusive' one. The radiographs of the patients who were treated in the three centres during the indicated period were available. However, that if one accepts the view that Perthes' disease radiologically can affect both hips at the same time, the relative incidence of bilateral disease is higher than the figures found in the literature. In the present series

ld be almost 50 per cent but because of
s, no firm conclusions can be drawn
arding the relative frequency of the
erent types of the disorder.

It is important to note in the three
erent types of bilateral Perthes' disease,
ptoms — however minor — were referable
only one hip during the whole course of
disease

The first type of bilateral disease, when
h hips show fragmentation concurrently is
uniscent of a mild form of multiple
physal dysplasia (Griffiths & Witherow
'77), although a radiological survey did not
show other epiphyseal abnormalities

n fewer than half of the patients in this
dy the disease affected only one femoral
ital epiphysis. Symptoms were referable to
y this affected hip and no abnormalities
ld be detected in the unaffected hip, and
these patients had undisputable unilateral
'rthes' disease, and the study of their
liographs has been included in an earlier
ort (Nevelos et al 1977)

In a small proportion of patients a clear
ie interval between the onset of
biological changes in the two hips was
erved. It ranged from 6 months to 4 years.
re important features of this type of Perthes'
sease are that symptoms were referable to
th hips alternately at the onset of each
ndition and that during the first attack the
ptomless side was clinically and
diologically normal. Although these patients
re designated as having had 'bilateral'
rthes' disease, it might be more appropriate
consider them as having suffered two

parate and unilateral attacks. This type of the
sease has, perhaps, more in common with the
ry rare 'recurrent' form of Perthes' disease, in
hich the second attack affects the same rather
an the contralateral hip. Three such cases
ve been reported (Kemp et al 1971,
erkreim & Foss Hauge 1976). The three other
ses of 'recurrent' Perthes' disease had all had
lateral disease at the first attack and, after
-aling, suffered a second, unilateral attack.
Kemp et al 1971, Katz 1973, Axer & Hendel
1977).

It is suggested, therefore, that bilateral
Perthes' disease is the form of the condition
when, despite unilateral symptoms,
radiological abnormalities of equal or
different severity affect both capital femoral
epiphyses simultaneously

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SCINTIGRAPHIC EVALUATION OF THE SEVERITY OF PERTHES' DISEASE IN THE INITIAL STAGE

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A method of grading Perthes' disease according to the involvement of the femoral capital epiphysis is presented. ^{99m}Tc pyrophosphate bone scintigraphy was performed on patients in the initial stage of Perthes' disease. An estimate of the femoral head involvement was made based on the size of the area with decreased activity visible on the scintigraphic image. The estimate allowed classification into one of four grades of severity of involvement. A comparison was made between the involvement seen on the scintigraphic image and the involvement later seen on radiographs. The importance of early diagnosis and treatment could be demonstrated.

Key words: bone, epiphysis, hip, Legg Perthes' disease, osteochondritis, necrosis, radiisotopes.

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Perthes' disease is in most cases characterized by a typical radiological appearance, but the degree of femoral head involvement differs. Lateral (1971) grouped the disease according to the amount of femoral epiphyseal involvement seen on the radiographs in the fragmentation stage. A relation between the severity and the end result was thereby demonstrated. This longitudinal grouping is, however, only possible relatively late in the course of the disease, and the influence of the early treatment given cannot be evaluated. Using ^{18}F scintigraphy Lohr (1973) demonstrated areas both with decreased and increased activity in the femoral epiphysis in Perthes' disease. More recently, ^{99m}Tc -labelled complexes have been the agents of choice in bone scintigraphy. Using ^{99m}Tc -pyrophosphate it has been possible to demonstrate a pathological image showing only decreased activity in the very early stage, even before radiological changes

are visible (Danigelis et al 1975, Fasting et al 1978).

The purpose of the present paper is to demonstrate the possibility of a scintigraphic grading of the severity of Perthes' disease according to the size of the area with decreased activity seen on the gamma camera picture. This in turn gives an opportunity to evaluate the effect of early treatment.

PATIENTS AND METHODS

This investigation was performed to evaluate scintigraphy in the initial stage of Perthes' disease. Only patients examined within the first 4 months after onset of symptoms and having typical radiological signs of Perthes' disease were included. The material thereby consisted of 18 patients with Perthes' disease in 20 hips, 3 females and 15 males. Their ages ranged from 2.5 to 11 years, with a mean of 5.4 years. Thirteen right and seven left hips were involved. The mean duration after the onset of symptoms at the first

examination was 26 months, at which time treatment was commenced. All patients were treated with skin traction for about 4 weeks. Thereafter non-weight-bearing was practised using bed rest, a hip plaster spica, crutches or a three lateral socket until the radiological remodelling stage was evident.

Bone scintigraphy was performed at the time the patient first presented using a gamma camera (Pho/G

11 mCi

et al

with a

detailed study and quantification of the area with decreased activity in the capital femoral epiphysis.

Since the size of the area showing decreased activity differed greatly between hips, the hips were divided into one of four scintigraphic grades. The grading was designed to correspond as closely as possible with the radiological grouping of Catterall (1971).

Grade 1 Decreased activity involving a minor part (roughly 1/4) of the capital femoral epiphysis.

Grade 2 Decreased activity involving a moderate part (roughly 1/2) of the epiphysis (Figure 1).

Grade 3 Decreased activity involving most (roughly 3/4) of the epiphysis (Figure 2).

Grade 4 Decreased activity involving the whole epiphysis (Figure 3). The subjective estimation of the scintigraphic grade in each case was performed blindly by the collaboration of two investigators.



Figure 1 The radiograph and the bone scintigraphic image of a 4-year-old boy with Perthes' disease in the right hip for 3 months. Scintigraphic grade 2 in the right hip. Normal evenly distributed activity in the left epiphysis.



Figure 2 The radiograph and scintigraphic image in a 6-year-old with Perthes' disease in the right hip for 3 months. Scintigraphic grade 3 in the right hip. Evenly distributed activity in the left hip.



Figure 3 The radiograph and scintigraphic image in a 4-year-old with Perthes' disease in the left hip for 2 months. Scintigraphic grade 4 in the left hip. Evenly distributed activity in the right hip.

The patients had their hips not examined in both AP and the L positions, and the examination was repeated to 5 month intervals. Normal radiographs at first examination were found in most hips. Typical changes during the early disease

Later in the course of the disease in the fragmentation stage, a radiological grouping from 1 to 4 was performed according to the degree of epiphyseal involvement (Catterall 1971)

Wilcoxon's test was applied to test for statistically significant differences (Wilcoxon 1947). The differences were considered significant when $2\alpha < 0.05$

RESULTS

The nuclear medical examination revealed decreased activity in the entire capital femoral epiphysis in nine hips corresponding to scintigraphic grade 4 (Table 1). Four hips showed decreased activity of scintigraphic grade 3 and seven hips of scintigraphic grade 2. No hips had decreased activity corresponding to grade 1. The age of the patients and the duration of symptoms did not differ among these grades.

Grouping according to Catterall (1971) was performed in the fragmentation stage (Table 2). The age of the patients was almost the same in each of these groups but the duration of symptoms before the start of treatment was less in radiological group 1.

When comparing the severity of the disease seen on the scintigraphic image in the initial stage with the subsequent radiological evaluation three different courses could be demonstrated (Figure 4). The first consisted of seven hips which were unchanged in severity from the scintigraphic grading to the radiological grouping. The second comprised eight hips which were found to have less

Table 2 Results of radiologic grouping in fragmentation stage in 20 hips with Perthes disease (Catterall 1971). Mean age in years and mean duration of symptoms in months when treatment was started

Radiologic group	Number of hips	Age	Duration
1	11	4.5	0.5
2	4	6.2	2.8
3	10	5.8	2.6
4	4	4.8	3

femoral head involvement in the radiographs than seen at scintigraphy, i.e. the scintigraphic grade was more severe than the radiological, they had "improved". The third consisted of five hips that had changed from a scintigraphically less severe grade to a radiologically more severe group, they had "worsened". In Table 3 a comparison is made between these three disease courses. A difference in duration of symptoms before the treatment started was apparent. The treatment had been started significantly ($2\alpha < 0.05$) earlier in those cases whose scintigraphic grade was more severe than

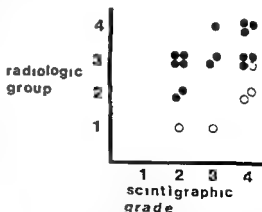


Figure 4 The comparison between the radiologic grouping (Catterall 1971) and the scintigraphic grading. ● Cases treated within 4 months after onset of symptoms ○ Cases treated within 1 month after onset of symptoms

Table 1 Results of scintigraphic grading in 20 hips with Perthes' disease in the initial stage within 4 months after onset of symptoms. Mean age in years and mean duration of symptoms in months when treatment was started

Scintigraphic grade	Number of hips	Age	Duration
1	0		
2	7	4.8	2.7
3	4	5.5	2.5
4	9	5.7	2.1

Table 3 Comparison of the scintigraphic grading of Perthes' disease in the initial radiological and radiological grouping in the fragmentation stage (Catterall 1971) in 20 hips. Mean age in months and duration of symptoms in months when treatment was started

	Number of hips	Sex		Side		Age	Duration
		Male	Female	Right	Left		
Radiologic group less severe than scintigraphic grade	8	5	3	5	3	6	15
Radiologic group more severe than scintigraphic grade	5	5	0	4	1	5½	22
Radiologic group similar to the scintigraphic grade	7	7	0	3	4	4½	14

their radiological group. The mean duration of symptoms being half (15 months) that of the other two disease courses (30 and 32 months). All five hips in which treatment was started within 1 month after the onset of symptoms had a less severe radiological group than scintigraphic grade, i.e. they had "improved".

DISCUSSION

Catterall (1971) classified Perthes' disease into four radiological groups and demonstrated the prognostic value of this. Katz (1973) made a classification into three different groups and also he found an unmistakable association of better results with a milder form of epiphyseal involvement and poorer results in cases with total epiphyseal involvement. A major determinant for tracer uptake is bone vascularity (Siegel et al 1976). The areas seen with decreased uptake of the tracer should therefore be the ischaemic areas of the caput epiphysis. Revascularization usually does not take place before 4 months after the start of the disease (Jonsater 1953, Larsen & Reimann 1973). As the bone scintigraphic examination in the present study was performed within 4 months after the onset of symptoms, the areas in the epiphysis with decreased uptake should therefore correspond to areas with decreased

blood flow and therefore may be threatened by bone necrosis at the beginning of the disease. It seems essential that a quantitative estimation of the activity is as soon as possible in the course of the disease and before revascularization has occurred. This provides a new method of differentiating patients with different degrees of epiphyseal involvement in the course of Perthes' disease and a sound basis on which to judge the effectiveness of different treatments. A quantification of the tracer uptake at a later stage as performed by Siegel (Morley et al 1978) does not reflect the severity of disease and may be the reason why no correlation with the radiological findings nor the results was found.

The treatment of Perthes' disease is a matter of dispute not only concerning a type of treatment, but also whether any treatment has any influence on the disease at all (Sundt 1949). Little attention has been paid to the problem of early treatment although Lauritzen (1975) and Fasting et al (1978) found better results when treatment was started shortly after the first radiological signs. In the present investigation the scintigraphic grading was designed to complement the widely accepted radiological grading. The difference between the scintigraphic grading in the initial stage and the radiological grouping in the fragmentation stage may reflect the influence of the treatment.

and/or the natural course of the disease in this early period. In the present study, treatment seemed in most cases to have little influence on the course of the disease, the area with bone necrosis seen on the radiographs being as large as, or larger, than the area with decreased activity on the scintigraphic image. However, early treatment seems to have an influence on the course of the disease. In the present study hips treated within 1 month after the onset of symptoms all improved (radiological grouping is more severe than scintigraphic grading). There was also a statistically significantly shorter duration of symptoms before the start of treatment in hips that had improved compared with the others. This supports the view that early treatment is of importance in Perthes' disease. It may be possible to change the course into a milder abortive form by very early treatment or to prevent bone necrosis in some cases (Emr et al 1973, Fasting et al 1978).

For clinical purposes bone scintigraphic examination with ^{99m}Tc -pyrophosphate is a useful supplement to the radiological examination. The examination can be repeated and the revascularization and new bone formation can be followed in the different stages of Perthes' disease.

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DISTAL TRANSFER OF THE GREATER TROCHANTER IN COXA VARA

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Seven patients (nine hips) who suffered from coxa vara were treated by distal transfer of the greater trochanter. The operation eliminated or markedly diminished the preoperative Trendelenburg sign, thus improving gait. In three patients (four hips) operated upon at the ages of 9 and 12 years, the initial coxa vara was converted into an almost normal valgus femoral neck. There was one poor result due to technical failure.

Key words: coxa vara, trochanter major transfer

Accepted 26 xii 79

Infantile Coxa Vara is an uncommon condition with various etiologies (Sharrard 1979). Its features have been widely described and its association with avascular necrosis complicating treatment of congenital dislocation of the hip are well documented (Salter et al 1969, Gage & Winter 1972, Laurent 1953, Jore 1974, Weiner et al 1977). It may result in shortening and widening of the femoral neck, relative hypertrophy of the greater trochanter and cause a typical limp or waddling gait, very like that in congenital dislocation of the hip, due to inefficient gluteal muscles. These patients have limited abduction of their hips and a positive Trendelenburg's sign.

Correction of gluteal insufficiency due to the short femoral neck, which usually has a marked varus angulation, is achieved by distal transfer of the greater trochanter (Cohen 1971, Westin personal communication 1976). The purpose of the present paper is to demonstrate the value of this operation in a series of seven patients with nine affected hips.

PATIENTS

During the years 1973-1978, seven patients suffering from coxa vara were treated by distal transfer of the greater trochanter. All our patients were females whose age ranged between 4 and 25 years (average 13.5 years). In two patients both hips were involved. All of them had a marked



METHOD

The greater trochanter was osteotomized with a Gigli saw and transferred distally 3-4 centimeters. Fixation was achieved by two compression screws or by two Steinmann pins.

The hip was immobilized in abduction for 6 weeks. In three patients a hip spica was used whereas in the others immobilization was achieved by two straight knee casts (tutors) held apart by a broom stick. Six weeks following operation, hip exercises and weight bearing were started.

Follow-up examinations at 3-month intervals included assessment of pain, limp, Trendelen-

transfer of the greater trochanter

Length of follow-up (years) (months)	Pain	Lump	Trendelenburg sign after operation	Limb length discrepancy after operation	Remarks
6	Occasional	Only when tired	Minimal	1 cm	
5	None	—	Minimal	2.5 cm	
3	10	None	Minimal	1.5 cm	
3	10	Occasional on the left side	L-negative R minimal		Originally L-CDH
3	Occasional bilateral	None	Negative	None	
1	1	None	+	2.5 cm	
	3	+	Minimal	2.5 cm	Pseudarthrosis. The screw broke



Figure 2 Case 2 5 years after operation. Note the corrected femoral neck shaft angle 128° and the contour of the almost normal femoral neck.

performed and maintained in abduction casts for 4 months. Avascular necrosis of both femoral heads manifested itself on the radiographs with flattening and fragmentation of the ossifying nuclei. Recovery took 4 years and the result was a bilateral coxa vara and coxa magna.

At the age of 12 years the patient had a typical Trendelenburg gait and limited abduction in both

hips. The femoral neck shaft angle was 105° in both hips (Figure 3).

Distal transfer of the greater trochanter was performed on both sides simultaneously at the one operation. The hips were immobilized for 6 weeks in abduction casts. On re-examination 3 years and 9 months after operation there was no lump. A residual minimal Trendelenburg sign was elicited on the right side. The femoral neck shaft angle was 130° on both sides (Figure 4).



Figure 3 Case 4 involvement of both hips. Note the impingement of the trochanter on the acetabular rim limiting abduction.



Figure 4 Case 4, 3 years and 10 months after operation. Note the correction of the varus and elimination of mechanical hindrance of abduction.



Figure 5 Case 7 standing radiograph. Note broken screw and the non-union of the trochanter.

RESULTS

The clinical results are summarized in Table 1. In all the patients the gait was improved by diminishing or eliminating the Trendelenburg sign.

Limb length discrepancy was not affected except in one case in whom it was diminished. In one patient (No. 7) (Figure 5) a too early mobilization resulted in screw breakage and non-union.

The radiographic results summarized in Table 2 demonstrate a change of the coxa vara into an almost normal femoral neck shaft angle in three patients (four hips).

DISCUSSION

Avascular necrosis of the femoral head complicates the closed treatment of congenital dislocation of the hip (Gage & Winter 1972, Weiner et al 1977). However, it can affect the normal hip (Gore 1974) as well. Its incidence is reduced by adequate pre-manipulative traction and adductor tenotomies (Salter et al 1969, Gage & Winter 1972, Gore 1974, Weiner et al 1977).

In the patients reported here no traction was performed and in all of them diagnosis of congenital dislocation was delayed and treatment started when the children were older than 7 years, thus adding another risk factor which could contribute to the development of avascular necrosis (Gage & Winter 1972, Weiner et al 1977). This vascular impairment is however one of the etiological factors in this series characterized all the patients included in the study.

Distal transfer of the greater trochanter in cases of coxa vara associated with muscular insufficiency, was introduced in our department by the late Professor Kohn in 30 years ago, and is used for the same indications by others (Cohen 1971, Weis et al 1976). This operation resulted in improvement in all our patients by diminishing the marked Trendelenburg sign in six hips and eliminating it completely in two hips.

Residual limp was noted in two patients in both, the affected limb was 2.5 cm shorter than the normal one in one patient (Case 7), one of the femoral screws was broken (Figure 5) and non-union between the trochanter and the femoral shaft was noted. This was due to technical failure.

Table 2 Radiographic results

Case no	Neck shaft angle before operation	Neck shaft angle after operation	Femoral head
1	—	L 115° R 145°	Round
2	115°	128°	Round
3	—	120°	Bifid
4	R 105°	130°	Coxa magna
	L 105°	130°	Coxa magna
5	R 115°	115°	Non spherical
	L 115°	115°	
6	115°	125°	Coxa magna
7	120°	120°	Coxa magna

nobilization One patient (Case 1) complained of limp only following physical exercises or a long walk. This could be attributed to some muscle weakness in the hip which had been operated on twice. Three patients reported occasional pain, which did not interfere with their daily activities.

Comparison of the radiographs before operation and at follow-up examination revealed that in three patients (four hips), the angle between the femoral neck and shaft increased between 10 and 15°, thus converting the initial varus into an almost normal valgus neck. With angular correction remodeling of the femoral neck also occurred. Of these three patients two were operated upon at the age of 12 years and one at 9½ years.

In two patients who were older than 16 years when operated upon angular correction did not occur.

In the younger age group distal transfer of the greater trochanter is a good alternative to a conventional valgus osteotomy. Its main disadvantage is that usually the limb is not lengthened as in a valgus osteotomy. But its advantages are that the femoral head remains in the acetabulum, and that it is a much simpler procedure. However, attention has to be paid to careful operative technique, such as osteotomizing the trochanter from its base in the digital fossa, and excising the bony protuberance which might remain between the femoral head and the osteotomy site, thus contouring the femoral neck.

In conclusion, considering the cases reported above, distal transfer of the greater trochanter yields good results by diminishing markedly the Trendelenburg sign and thus improving gait. When the operation is performed before the age of 12 years, correction of the coxa vara and femoral neck remodeling will occur, yielding a very good result.

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EXTENSION DEFICIT AND LATERAL INSTABILITY IN DEGENERATIVE DISEASE OF THE KNEE

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During the period October 1975-June 1977, 70 Marmor knee arthroplasties were performed. The operative procedure provided a good opportunity to study the anatomical conditions *in vivo*. The causes of extension deficit and lateral instability of the knees were analysed in a prospective investigation. Thirty-seven out of 69 knees had an extension deficit exceeding 10° preoperatively. At operation a bony impediment to extension was found in 32 of these 37 knees, and by removal of this obstruction the extension deficit was relieved in 31 of the knees. At radiography a bony impediment was demonstrated preoperatively as a cause of an extension deficit in 29 of the 32 knees. No false positive diagnosis was made radiographically. Varus or valgus instability exceeding 5° was observed preoperatively in 42 of the 70 knees. Lateral stability was achieved in all knees at operation by compensating for the intra-articular loss of cartilage and bone with the Marmor module system. Macroscopically intact collateral ligaments were found in all knee joints even in those severely affected by rheumatoid arthritis. All knees except three showed lateral stability 1 year postoperatively.

Key words: flexion contracture, knee instability, Marmor knee, polycentric knee arthroplasty, osteoarthritis of the knee, rheumatoid arthritis of the knee.

Accepted 28 xii 79

Rheumatoid arthritis and osteoarthritis can give rise to severe deformities, limitations of movement and instability of affected joints. In the literature sporadic reports and assumptions can be found concerning the cause of the extension deficit and lateral instability in degenerative disease of the knee. Helfet (1974) considers limited extension and reduced mobility of the knee to be due primarily to soft tissue contracture. Several authors (Marmor 1973, Smilie 1974, Brattstrom 1977, Gschwend 1977, Cavendish & Wright 1978) have mentioned bony obstruction as one of the causes of an

extension deficit in the knee, but this idea seems to have received little attention.

Coomes (1962) concluded that there is some lengthening of the collateral ligaments in knees affected by rheumatoid arthritis. He did not state, however, whether the radiographs in his investigation were taken during weight-bearing, and his conclusion is therefore not entirely convincing. The laxity of the ligaments in severely affected knees might be due largely to loss of bone and cartilage between the ligament attachments as a result of the degenerative joint disease. Coomes' experimental studies show that as

soon as the laxity of the ligaments has been tightened, they behave almost normally as regards elasticity. The absence of a meniscus alone does not cause clinically measurable varus-valgus instability (Markolf et al 1976). Some authors (Marmor 1967, Gunston 1971, Aghetti & Rinonapoli 1977, Cavendish & Wright 1978, Freeman et al 1978, Goodfellow & O'Connor 1978) assume that the instability is partly due to destruction of cartilage and bone in the joint.

Arthroplasty of the knee is reserved for joints that are severely damaged by a degenerative disease, which often threatens the independence of the patient (Brattstrom et al 1977). The extensive surgical exposure of the knee joint permits the study of the anatomical conditions *in vivo*. In a previous paper (Wigren et al 1978) we have reported the occurrence of meniscal regeneration observed at reoperations following polycentric knee arthroplasty. In connection with knee arthroplasty a prospective study was performed on the occurrence of a bony block as the cause of extension deficit. The reason for lateral instability was also studied, and the results are described in this paper.

PATIENTS AND METHODS

During the period October 1975–June 1977, a Marmor arthroplasty was performed on 70 knees, 46 in women and 24 in men. In 10 women and 5 men the operation was bilateral. In 75 per cent of the knees the diagnosis was rheumatoid arthritis (RA) and in 25 per cent osteoarthritis (OA). One of the knees with OA exhibited sequelae from a fracture of the tibial condyle. The ages of the RA patients varied between 29 and 79 years and those of the OA patients between 60 and 77 years. The age and sex distributions in the two groups are presented in Figure 1.

At preoperative clinical and radiographic examination of 69 of the 70 knees (one knee is excluded because of inadequate records), the number of knees with a clinical extension deficit exceeding 10° , measured with a goniometer was recorded. The extension deficit of the knee joint is defined as the angle between the neutral position of the joint (0°) and the maximal passive extension achievable. Furthermore a record was

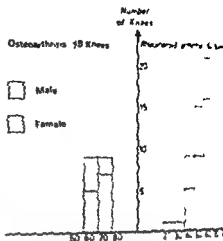


Figure 1 Distribution of patients by age, sex and diagnosis (number of knee).

made of the occurrence of a bony block impeding to extension on the lateral and lateral view taken with the knee in full extension. Registration was also made of extension deficit exceeding 10° prior to administration of epidural analgesia. A tourniquet was then applied and the knee was opened through a medial parapatellar incision. As the first measure before the Marmor prosthesis was inserted any bone present in the extension was removed when the knee was examined again.

Preoperatively with the patient in the varus or valgus instability error of the knee was noted. Measurement was made with a goniometer with the knee in maximal extension. The result was then compared with the degree of extension achieved after insertion of the Marmor prosthesis and at follow-up postoperatively.

As the surgical technique in the Marmor arthroplasty does not allow total free division of the ligaments, this was carried out preoperatively in human joints with severe knee damage and instability due to rheumatoid arthritis.

RESULTS

Preoperatively 37 of the 69 knees had an extension deficit exceeding 10° on clinical examination. Of these 37 knees 15 were affected by rheumatoid arthritis and 22 by osteoarthritis. The extension deficit in the knees varied from 15° to 45° and the

and from 15 to 40° in the OA group, with a mean value of 27° in the former group (Table 1) After administration of epidural anaesthesia there were 32 knees with an extension deficit exceeding 10°. Thus in 5 knees the anaesthesia caused the extension deficit to disappear. Preoperatively a bony block impeding extension was observed radiographically in 29 of these 32 knees (Table 2). There were no radiographic signs of bony impediment in any of the other knees (Figure 2). After removal of the bony prominence which was found in 32 knees an extension deficit exceeding 10° was found in only one of them. In this patient the preoperative extension deficit was 55°. After

Table 1 Preoperative distribution of 37 knees with an extension deficit exceeding 10° between the diagnoses rheumatoid arthritis (RA) and osteoarthritis (OA)

	RA	OA
Number	32	5
Ext. deficit	15 55	15 40
Mean	27	

Table 2 The number of knees with an extension deficit exceeding 10° after administration of epidural anaesthesia was 32. In 29 of these a bony impediment to extension was observed at preoperative radiography

	RA	OA
Number	28	4
X ray with bony block	25	4

Table 3 Varus or valgus instability of more than 5° was found preoperatively in 42 out of 70 knees with the distribution shown between the diagnostic groups. One year postoperatively all knees except three were laterally stable

	RA	OA
Preop instability	30	12
Postop instability	2	1



Figure 2 Radiograph showing a typical bony prominence on the anterior part of the tibial plateau preventing full extension. It has made an impression on the femoral condyle proving that the bony block is the cause of the extension deficit

removal of the bony prominence on the anterior lip of the tibia 20° remained

At preoperative examination varus or valgus instability exceeding 5° was found in 42 out of 70 knee joints, of which 30 were in patients with RA and 12 in patients with OA (Table 3). In 40 joints the instability was 5–10° and in two RA joints it amounted to 15° with the knee in maximal extension. At operation the collateral ligaments appeared intact in all knee joints. In the RA knees the anterior cruciate ligament was often missing while the posterior cruciate ligament was intact. In the OA knees the cruciate ligaments were unaffected. The lateral instability was caused mainly by bone destruction and loss of



Figures 3 and 4 Dissection of collateral ligaments from cadaver human knees with severe degeneration due to rheumatoid arthritis. It is clear that the loss of bone and cartilage in the joint is mainly responsible for the lateral instability. The collateral ligaments (arrow) are intact, and the medial is stretched by valgus force (Figure 3) and folded by varus force (Figure 4)

follow-up. At later follow-ups these were considered to be laterally stable. Anterior drawer phenomenon was observed clinically in any of the knees postoperatively.

In autopsy cases with rheumatoid arthritis with severely affected joints the collateral ligaments were easily identified and intact, and the instability was due to loss of bone and cartilage especially at the articular surface where a defect could be seen (Figures 3 and 4).

DISCUSSION

In 37 out of 69 knees there was a lateral deficit of more than 10° . A deficit of 10° was considered the smallest clinically measurable lateral instability. Administration of epiphyseal growth arresters

cartilage and bone on the tibial and femoral condyles, and by the use of the module system of the Marmor prosthesis lateral stability was achieved on the operating table in all knees. One year postoperatively all knee joints except three remained stable. These three knees showed lateral instability of $\leq 5^\circ$ with the knee extended. One knee had been operated on several times previously for a fracture of the lateral tibial condyle. The patient had also had a peritrochanteric femoral fracture treated with Ender nails and had considerable atrophy of the vastus medialis muscle. Two of the knees displayed instability of less than 5° at the 1-year

reduced to 32. In 31 of them full extension was achieved after removal of the impeding bone, which was thus the cause of the extension deficit in these cases. In the one knee in which the extension deficit did not disappear, there was in addition to the mechanical bony impediment also a soft tissue contracture. We found that the radiographic findings gave high diagnostic reliability. There were no false positive radiographic findings. In addition to the bony prominence of the anterior lip of the tibia (Johnson 1959), an impression on the femoral condyle should also be visible as proof of the functional impairment (Figure 2). This study shows that the most common cause of an extension deficit in these severely damaged knees is a prominence of bone on the tibial plateau forming a mechanical obstruction and not a soft tissue impediment as the word flexion contracture implies. *The term flexion contracture should be reserved for a flexion deformity in which a mechanical bony impediment to extension can not be demonstrated radiographically.* Only in knees in which the deficit disappears under anaesthesia is it possible to apply conservative treatment. This opinion is in agreement with that of Smilie (1974). It seems to us that in knee joints with restricted extension, radiography in the lateral projection with the knee extended to the maximum should be performed. *If a bony impediment is demonstrated radiographically, conservative treatment of the extension deficit has no chance of success.* Information regarding the radiographic findings should be given to the physiotherapist when the patient is referred for muscle exercises and prophylactic treatment against increasing contracture. Otherwise extensive exercises may give rise to tibial or femoral fracture of the soft rheumatic bone (Brattström 1977).

Lateral instability of more than 5° was found preoperatively in 60 per cent of the knees in this study. Five degrees was considered to be the lower limit for clinically reliable measurements (Markolf et al 1976). At operation lateral stability was achieved in

all knees by replacing the lost bone and cartilage with the modules of the Marmor prosthesis. All knees except three were still stable at follow-up 1 year postoperatively. This would not have been possible if the collateral ligaments of the knee joints had not been intact. Further proof that these ligaments were not destroyed even in knee joints with severe rheumatoid degeneration was the macroscopic observation of undamaged ligaments in the autopsy material. This finding corresponds to the ligament stability demonstrated experimentally by Coomes (1962). It is thus concluded that *the collateral ligaments are intact and latently retain their function despite severe bone destruction in the arthritic knee. The loss of bone and cartilage is the principal cause of the lateral instability.* It is therefore essential when performing polycentric knee arthroplasty to choose a surgical technique which will not affect the attachments of the collateral ligaments. Marmor's recommendation (1973) of drilling out the bed for the tibial part of the prosthesis with retention of the posterior and lateral tibial margin instead of an L-resection of the tibial plateau would seem a safe method.

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Figures 3 and 4 Dissection of collateral ligaments from cadaver human knees with severe degeneration due to rheumatoid arthritis. It is clear that the loss of bone and cartilage in the joint is mainly responsible for the lateral instability. The collateral ligaments (arrow) are intact, and the medial is stretched by valgus force (Figure 3) and folded by varus force (Figure 4).

cartilage and bone on the tibial and femoral condyles, and by the use of the module system of the Marmor prosthesis lateral stability was achieved on the operating table in all knees. One year postoperatively all knee joints except three remained stable. These three knees showed lateral instability of $\leq 5^\circ$ with the knee extended. One knee had been operated on several times previously for a fracture of the lateral tibial condyle. The patient had also had a pertrochanteric femoral fracture treated with Ender nails and had considerable atrophy of the vastus medialis muscle. Two of the knees displayed instability of less than 5° at the 1-year

follow-up. At later follow-ups these joints were considered to be laterally stable. The anterior drawer phenomenon was not observed clinically in any of the knees postoperatively.

In autopsy cases with rheumatoid arthritis and severely affected joints the collateral ligaments were easily identifiable and found intact, and the instability was due to loss of bone and cartilage especially at the tibial articular surface, where a distinct area could be seen (Figures 3 and 4).

DISCUSSION

In 37 out of 69 knees there was an extension deficit of more than 10° . A deficit of at least 10° was considered the smallest that was clinically measurable with certainty. The administration of epidural anesthesia to the number of knees with an extension deficit

RECURRENT DISLOCATION OF THE PATELLA

Treatment by ■ Modification of the Method of McCarroll & Schwartzmann

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In a retrospective examination of 40 knees operated on according to a

cent Twelve per cent had recurrence of the dislocation. There was very little correlation between the preoperative X ray and the final results. Open epiphyseal plates were found to be a contraindication for the operation. The duration of the condition and the number of dislocations had no bearing on the end results. The operative method is recommended for both traumatic and non traumatic dislocations of the patella.

Key words: dislocation, injuries, knee joint, patella, radiography, tendon transfers.

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The treatment of intermittent dislocation of the patella remains a controversial problem, giving rise to a wealth of different operative methods, according to Cotta (1959) the number is about 140. In the light of theoretical and clinical experience, a procedure combining active and passive correction as described by McCarroll & Schwartzmann (1945) appears to be superior to other methods (Thestrup Andersen 1955, 1959; Heywood 1961; Crosby & Insall 1976). McCarroll & Schwartzmann have applied the method on patients suffering from severe cases of patellar dysplasia, most often with chronic dislocation as seen for instance after poliomyelitis. In the Department of Orthopaedic Surgery T-3 at Gentofte, the dominant group of patients with intermittent dislocation of the patella have for a number of years been young athletes with trauma as the

basic aetiological factor. The purpose of the present study is to assess in a retrospective examination the clinical and roentgenographic results of a modification of the procedure of McCarroll & Schwartzmann, carried out on the above-mentioned clientele.

PATIENTS AND METHODS

During the period from 1971 until 1975 a consecutive series of 39 patients underwent operation and 37 were followed up. Three of these had both knees operated on, so that a total of 40 knees were subjected to examination. Mean age was 19.1 years (range 11-40) and the follow up time was 3.8-7.6 years (mean 5.6 years). Males and females were equally represented. In all cases the indication for operation was recurrent dislocation of the patella, defined as complete dislocation more than once.

The operative procedure consists of a transposi-

tion of the tibial tubercle medially and distally until normal articulation of the patella is considered to be obtained. The operation is called a self-loc

rectional

Schwartzmann consists of a semitendinosus tendon transfer into a subperiosteal longitudinal tunnel in the ventral part of the patella. The passive correctional procedure as mentioned above is retained, while the active part of the operation is modified by loosening the distal edge of the pes anserinus and the semitendinosus tendon is then swung proximally so that it can be sutured to the distal-medial edge of the patella and to the proximal part of the patellar ligament. The patient is immediately mobilized with full support in a knee plaster capsule which is removed after 6 weeks. After this active training is prescribed.

The clinical results of the operation were classified according to Table 1.

Roentgenographic examinations. The level of the patella is assessed as prescribed by Insall & Salvati (1971) though is modified by Jacobsen &

referred to by Thstrup Andersen 1955) were used. In tangential X ray exposures of the femoro-patellar joint by Furmaier's technique morphology and subluxation were assessed as prescribed by Wiberg (1941) Brattstrom (1964) Merchant et al (1974), and Laurin et al (1978) (Figure 1).

Statistical calculations are based on Fisher's exact test with 5 per cent as the level of significance.

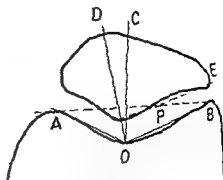


Figure 1 Axial view of the right patellofemoral joint ("Merchant view"). The sulcus angle of Brattstrom is AOB. Mean 142 degrees ± 4 degrees. The congruence of Merchant is DOC (DO bisects the sulcus angle). Mean -6 degrees ± 11 degrees. The lateral patellofemoral angle of Laurin is EPB. Normally it is never open medially.

RESULTS

The mean duration of hospital treatment was 3.8 days (range 2-10 days) and the rehabilitation period was 24-670 days (mean 100 days). Table 2 shows the final operative results.

There were only two complications, though serious ones. Out of nine patients with open epiphyseal discs one developed

Table 1 The criteria used for assessing the results of operation

EXCELLENT	No pain or stiffness no crepitus full range of movement no loss of function
GOOD	Minimal pain or stiffness minimal crepitus full range of movement, restriction of strenuous sports only
FAIR	Moderate occasional pain or stiffness moderate crepitus limitation of flexion less than 10 degrees moderate restriction of sports
POOR	Severe pain and stiffness with crepitus limitation of flexion over 10 degrees inability to maintain the body weight on the semiflexed knee complete restriction of sports
RECURRENCE	

Table 2 *Assesment of results*

RESULT	NUMBER OF KNEES	PERCENTAGE
EXCELLENT	17	43
GOOD	10	25
FAIR	4	10
POOR	4	10
RECURRENCE	5	12
TOTAL	40	

recurvatum with a 15 degree dorsal tilting of the tibial condyles, resulting in a marked feeling of instability. Another patient developed a recurrent patella dislocation accompanied by chondromalacia so severe that patellectomy had to be performed 3 years after the operation.

The poor results were due particularly to chondromalacia and reduction of quadriceps power. In five cases the patella remained unstable, relapsing into dislocation which was in most cases complicated by synovitis and chondromalacia.

Symptom yielding chondromalacia was found preoperatively in 11 patients. Of these eight patients became free of symptoms after the operation. On the other hand the presence of preoperative chondromalacia had no

bearing on the final result (Table 3). Five out of 21 knees without preoperative femoro-patellar pain developed postoperative chondromalacia.

The dislocations were considered traumatic in 75 per cent (30/40), of these 67 per cent (20/30) had a successful result compared with 78 per cent (7/9) of the habitual dislocations. This difference is not significant ($P > 0.20$). The duration of the condition and the number of dislocations were found to have no bearing on the final result.

Preoperative X-ray examinations revealed seven cases of patella alta six of which had traumatic dislocations. After operation one of these cases relapsed, while the remaining six were classified as excellent and good. Only in two did the level of the patella normalize, one with an excellent result, whereas the other relapsed.

Merchant's congruence angle (Figure 1) was preoperatively normal in all patients. Postoperatively no lateral subluxation was found, while medial subluxation due to overcorrection was in evidence in 10 cases (mean -36.6 degrees, s.d. 7 degrees) of which only five were classified as good. Brattstrom's sulcus angle was found to be normal in all cases. Laurin's angle was also found to be normal in all but one patient, where the angle was 0 degrees (Figure 1). This patient relapsed. We found no signifi-

Table 3 *The bearing upon the operative result of preoperative chondromalacia*

RESULT	+ CHONDROMALACIA		- CHONDROMALACIA	
	NUMBER OF KNEES	PERCENTAGE	NUMBER OF KNEES	PERCENTAGE
EXCELLENT	8	72	15	72
GOOD				
FAIR	1	9	4	19
POOR				
RECURRENCE	2	19	2	9
TOTAL	11		21	
NO INFORMATION 8 KNEES				

cant correlation between the end-result and Wiberg's patellar types

DISCUSSION

With a median hospitalization time of 3 days we are approaching that of meniscectomy, which in our department is 2.6 days. This short hospital stay can be partly attributed to mobilization as early as within the first 24 hours postoperatively.

Transposition of the tibial tubercle close to open epiphyseal discs involves the risk of the development of genu recurvatum owing to anterior epiphysiodesis. The recorded incidence varies from about 18 per cent (Crosby 1976) to 33 per cent (Heywood 1961). The authors arrived at 11 per cent (confidence limits 0.28-48.25, $P < 0.05$) in the present material, which should call for some caution.

Correction of patellar instability may remove the inconvenience of chondromalacia (Dandy & Poirier 1975). The present study has been able to confirm this observation, as 72 per cent (8/11) became free of symptoms after normal patellar stability had been obtained. In cases of continued instability chondromalacia disappeared in only 20 per cent (1/5). Only in five cases did postoperative chondromalacia develop, but in these it is worth noting that three patellae were medially overcorrected. If this finding is related to the high frequency of poor results in patients suffering from postoperative medial subluxation (10 cases), it should be stressed that during operation as much attention must be given to medial overcorrection as is given to a too distal transposition of the tibial tubercle.

The occurrence of patella alta was found mainly in cases of traumatic dislocation, which is at variance with the findings of Jacobsen & Metz (1976) of quite normal knee morphology in 10 patients with traumatic dislocations of the patella. That high-riding patella involves a predisposition to dislocation was established by Thestrup Andersen (1955,

1958) and by Insall et al. (1972), but a bearing on traumatic dislocations of the patella is not clear. The discrepancy is most likely to stem from the fact that among the patients of our material with high-riding patella, the majority were found to be Wiberg's patellar type III.

The preoperative assessment of femoropatellar X-ray parameters was deemed to be of little value with regard to predicting the operative effect. Thus indication for operation can be based on clinical findings exclusively.

It may be concluded that with a high degree of certainty and few complications the modified McCarroll & Schwartzman operation is capable of stabilizing the femoropatellar joint in patients with intermittent patellar dislocations of traumatic as well as of non-traumatic origin.

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Figure 3 Xerography of knee joints operated on by two different methods of anterior dislocation (Figure 2)

paralysis 3, fracture of the tibial tuberosity 3, suture granuloma 2, deep vein thrombosis 2, quadriceps rupture 1, anterior compartment syndrome 1, pulmonary embolus 1, fracture of the shaft of the tibia 1

The grade of change in the patellar cartilage according to Outerbridge (1961) was

Grade I 15 joints

Grade II 12 joints

Grade III 26 joints

Grade IV including patello-femoral arthrosis 15 joints

In this respect, there were no differences between men and women

At the follow-up, the patient's evaluation of the result of the operation indicated improvement in about 90 per cent (Table 2). The results in women were slightly but not significantly worse. The working capacity before the onset of disabling symptoms and the preliminary postoperative capacity are presented in Table 3. The patients who did

not work may have been students or not for reasons other than their knee condition. Before the onset of knee disability no

Table 2 Patients' evaluation of the results (per cent)

	Men	Women
Free from symptoms	27	14
Improved	9	13
Unchanged	1	0
Worse	1	1

Table 3 Working capacity before onset of symptoms and after surgery (patella)

	Before	After
Heavy work	16	6
Moderate	24	27
Slight	14	1
Very slight	6	1
Not working	2	

Table 4 Pain on walking up and down stairs (joints)

Sex	Pain	No pain
Men		
Before	37	1
After	9	29
Women		
Before	30	0
After	16	14

Table 5 Pain index on sitting with bent knees (joints)

Sex	Pain	No pain
Men		
Before	38	0
After	4	34
Women		
Before	30	0
After	9	21

Table 5 Pain index before and after anterior displacement of the tibial tuberosity (joints)

Sex	1	2	3	4	5	6
Men						
Before				10	12	16
After	21	11	2	3		1
Women						
Before				13	7	10
After	16	9		4	1	

More than 61 per cent of these patients had participated in sporting activities, the men more often than the women. After the operation, 56 per cent did so, the change being insignificant, although the results with regards to sporting capacity were slightly worse in women. After surgery, pain on walking up and down stairs improved significantly ($P < 0.001$) (Table 4), with a tendency for a

less satisfactory improvement in women. The ability to sit with bent knees without pain also improved significantly after surgery ($P < 0.001$) (Table 4). The pain index, which indicated considerable pain before surgery, shifted favourably in both sexes ($P < 0.001$) (Table 5).

In Table 6, the various residual signs and symptoms which may be generated in the patello-femoral joint are listed for both sexes separately. Note that, after surgery, a considerable amount of semi-objective signs and symptoms remained, most pronounced in women. Crepitations seem to have little to do with the symptoms of the patient since many, in fact most of those with crepitations, were otherwise free from symptoms after surgery. Also, tenderness of the tibial tuberosity, which is related to the operation rather than

Table 6 Residual patello-femoral signs in both sexes (joints)

		Men	Women	Significance
Stepping on chair	Able	36	22	$0.05 > P > 0.02$
	Unable	2	8	
Displacement	+	6	13	$0.05 > P > 0.02$
Pain	-	32	17	
Tenderness	+	10	12	n.s.
Medially	-	28	18	
Tapping pain	+	7	11	n.s.
	-	11	19	
Crepitations	+	22	21	n.s.
	-	16	9	
Tenderness of the tibial tuberosity	+	4	10	$0.05 > P > 0.01$
	-	34	20	

to the disease, was more frequent in women than in men

The arthrotomy disclosed a number of previously undiagnosed intra-articular conditions. In 15 joints, there was evidence of medial and in two of lateral femoro-tibial degenerative changes. These changes were slight and could not have been detected without arthrotomy or arthroscopy. In 12 cases, there were signs of synovitis and in 11 an ulceration of the femoral cartilage corresponding to the changes on the patella — "mirror defect". Anatomical changes of the Hoffa fat pad were seen in four cases, and inveterate anterior cruciate ligament ruptures in two. Over-growth of the synovial fringe on the joint cartilage was seen in two cases. There was one case of ruptured semi-lunar cartilage and finally in one joint a loose body.

Second follow-up

In the second follow-up study, 17 months later, only 47 joints were included. The patient's opinion was now compared between the first and the second examinations. In men there was further improvement in four cases whereas one patient, free from symptoms in the first follow-up, now claimed that he was worse than before the operation. In women, the second follow-up revealed slightly worse results. None of the women had improved further during the 17 months whereas six had changed for the worse, thereby reducing the initial result of about 90 per cent improvement to about 70 per cent improvement. With regard to working capacity, six men had changed to lighter work whereas four had changed to heavier work in the 17-month interval, in women, no less than eight had changed their working conditions but only one to a lighter job. With regard to sport, there were no changes of importance in either sex between the first and the second examinations. The pain index improved in no less than eight men and of these seven were rendered completely free from pain during this time period, whereas one was slightly

worse, changing one step in the pain index. In women, however, only two knees were better during this time interval whereas in six pain increased according to the index.

Otherwise, the findings of the second follow-up did not significantly deviate from those of the first examination.

Thigh circumference and range of motion

At the time of the first re-examination there was a decreased circumference of thigh amounting to, on average 1 cm (Table 7). There were no such differences in the second examination. At the second examination this difference had decreased significantly, on average 1 cm had been added to the thigh circumference. 17 months. At one of the measuring points on the thigh, the data even went so far as to indicate that the side to side difference had now been over-compensated for. This, however, is not so since the circumference of the thigh of the untreated leg also increased somewhat with time. In fact, at the second follow-up there was no longer any difference between the thigh circumference of the treated and the untreated legs. The range of motion was restricted in one sense only — there was a slight limitation — less than 10° — of the flexion motion which did not improve significantly between the first and the second examinations (Table 8). Full extension was recorded in all cases.

Analysis of poor results

In order to analyse probable causes of failure, the cases were arranged into two groups. Group 1 consisted of all knees that had improved in all the variables examined — 48 knees. These knees were compared with those 20 — Group 2 — that had shown no improvement with regard to at least one of the parameters of pain or dysfunction. Group 1 consisted of 33 men and 15 women whereas in group 2 there were five men and 15 women with a significant preponderance of women ($P \leq 0.001$).

Table 7 Circumference measurement (cm) (Bilateral surgery excluded)

Untreated minus treated			
1st examination	Average \pm 1 s.d.	N	Significance
Thigh 15 cm	-0.98 ± 1.52	56	$P < 0.001$
Thigh 25 cm	-1.01 ± 1.51	56	$P < 0.001$
Calf	-0.05 ± 0.73	56	n.s.
Treated			
1st examination minus 2nd examination			
Thigh 15 cm	-1.24 ± 2.54	39	$0.01 > P > 0.001$
Thigh 25 cm	-0.90 ± 2.42	39	$0.05 > P > 0.02$
Untreated			
1st examination minus 2nd examination			
Thigh 15 cm	-0.68 ± 1.93	39	$0.05 > P > 0.02$

Table 8 Range of flexion motion (bilateral surgery excluded)

1st examination	Average \pm 1 s.d.	N	Significance
Untreated minus treated	$-7.9^\circ \pm 13.7^\circ$	56	$P < 0.001$
1st examination minus 2nd examination	$-13.0^\circ \pm 11.6^\circ$	56	n.s.

Also, the women in Group 1 were significantly younger than the women in Group 2, 27 ± 13 and 37 ± 10 , respectively ($0.05 > P > 0.02$). In Group 1 there were 10/48 complications and in Group 2, 9/20 complications with a significant preponderance in Group 2 ($0.05 > P > 0.02$). In Group 2, all the complications were in women. Seven of the 13 joints with chondromalacia grade IV - arthrosis, belonged to Group 2, which indicates less satisfactory results in this type of patient, the difference, however, being non-significant.

Variation between methods

The modified method of anterior displacement (Figure 2) was equally distributed among Groups 1 and 2. Although the complications were somewhat - but not signifi-

cantly - fewer with the modified method, there were otherwise no differences in the results not even with regard to tuberosity tenderness. The degree of anterior displacement, measured on postoperative radiograms, varied somewhat (9.8 ± 2.5 mm) but this variation was not related to the results.

The data were also analysed with regard to whether shaving of the cartilage had been performed or not. There was a slight but not quite significant preponderance of women in the shaving group ($0.1 > P > 0.05$). The follow-up time was significantly ($0.02 > P > 0.01$) longer in the shaving group, which merely indicates that this procedure was more often undertaken during the first part of the trial period. There was a significant ($0.02 > P > 0.01$) shift towards more severe patello-femoral changes in those patients who had been shaved. Otherwise,

there were no initial differences between patients selected for the two types of treatment, nor did the results differ significantly in any of the measured variables. The two sets were also evenly distributed between Groups 1 and 2.

DISCUSSION

From the data in this study the conclusion must be drawn that anterior displacement of the tibial tuberosity is beneficial to patients with patello-femoral pain. There is in the data no indication as to how the cases should be selected. The finding of somewhat poorer results in women, and particularly in older women, in this study is confused by the fact that poor results in women were associated with complications of the surgery and the interaction of sex, complications and results cannot be clarified on the basis of our data. Shaving did not seem to add to or deduct from the results even if it must be taken into account that shaving was reserved for those patients with the most obvious gross anatomical changes. This is a prospective study without controls. In order to evaluate the placebo effect the material was investigated twice, which should permit an evaluation of the durability of the result. Only in women did the results deteriorate over the 17-month interval, whereas in men the results improved further in most of the variables evaluated. However, also in women a rate of improvement of about 70 per cent in repeated examinations over 30 months can not be explained as a placebo effect, taking into consideration the long-standing preoperative symptoms in these patients.

APPENDIX

Surgical treatment of chondromalacia patellae - an annotated bibliography

This bibliography attempts to survey the therapeutic approaches to chondromalacia patellae and to bring the reader up-to-date in this field.

Chondrectomy or patellar cartilage resection Budinger (1906-1908), Aleman (1928), K (1939), Wiles et al (1960), Wilppula & Valt (1971), Chakraverty (1972). *Chondro combined with drill holes* Pridie (1957), De et al (1966), Insall (1967, 1974).

Medial ridgeotomy Outerbridge (1961), Crooks (1967).

Subtotal patellectomy Diamond (1964), (1969), Groeneveld (1973).

Patellectomy, Friberg (1941), West (1941), Geckeler & Quaranta (1962), Bentley (1964), *Patellar prosthesis* McKeever (1955), DePalma et al (1960), Hanslik (1973), Levitt (1973).

Patelloplasty Cave et al (1945), DePalma & Campbell (1963).

Patellar surface allograft replacement Outerbridge & Dunlop (1975).

Medial shift of the tibial tubercle Goldthwait (1963), Trillat et al (1964), De Golski (1973).

Downward advancement of the vastus medialis muscle Outerbridge & Dunlop (1975).

Release of the lateral capsule Slocum et al (1973), Merchant & Mercer (1974), Ficat (1975).

Anterior displacement of the tibial tuberosity Maquet (1963), Bandi (1972), Vasseri & Sussenbach (1973), Lund & Nilsson (1980).

The most wide-spread procedure is without doubt the removal of degenerative cartilage from the joint surface of the patella. Good results with this method have been reported by Budinger (1906-1908), Aleman (1928), Silverskjöld (1939), Harrison (1939), Cave et al (1945), Wilppula (1947), Wiles et al (1956-1960), Wilppula & Valt (1971), Eriksson & Forsberg (1971), Vahvanen (1971), Eriksson & Forsberg (1971), Christman & Snook (1974), Herche (1974), Nilsson (1980).

In recent years two additional methods have been introduced, i.e. the lateral release of the patella (Slocum et al 1973, Ficat et al 1974) and the anterior displacement of the tibial tuberosity. The latter method was introduced by Goldthwait (1963) and promising results, although in a series only, have been presented by Bandi (1972) and Vasseri & Sussenbach (1973). The first series so far are by Maquet (1963) and Lund & Nilsson (1980).

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OPTIMAL CORRECTION IN HIGH TIBIAL OSTEOTOMY FOR VARUS DEFORMITY

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As a basis for determining the required correction in high tibial osteotomy

the angular change between the axes of the femur and the tibia is determined. The angular change is determined by the three-point technique. The angular change is determined by the three-point technique. The angular change is determined by the three-point technique.

way the desired correction can be calculated. For this patient series it was found that correction to between 3 and 7° valgus of the varus/valgus deviation (three-point technique) led to the best subjective rating of the end result by the patients. To compensate for the expected relapse after the operation another 1 or 2° may be added to the angular change at the operation. To avoid an increase in the instability of the knee a lateral capsule reconstruction should be performed.

Key words: gonarthrosis, optimal correction, tibial osteotomy, varus deformity

Accepted 30 x 79

When, in 1961, Jackson introduced high tibial osteotomy as a form of treatment for arthrosis of the knee with varus or valgus deformity he stated that the aim of the operation was "to make the leg look straight" (Jackson & Waugh 1961). Bauer and co-workers (1969) took radiographs of the knee joint with the patient standing. They obtained the best results when the lateral angle between the axes of the long bones (the FT angle) was between 164 and 177° and recommended that this should be the surgeon's objective.

Coventry (1973) used radiographs taken with the patient standing on both legs. The aim was to obtain an FT angle of between

167 and 170° after the operation. This figure was subsequently changed to 170-175° (Coventry 1979).

In an earlier article (Myrner 1980a) the author reported a randomized series in which the operation in one group of the patients aimed at a correction to 5° valgus, measured from the varus/valgus deviation as determined by the three-point technique (Edholm et al 1976, 1977).¹ In the other group a varus/valgus deviation of 0° was aimed at.

Though postoperative displacement of the osteotomy surfaces introduced variations in the end result (including those associated with the soft tissues), the study showed that when the correction to 5° valgus was successful within 2° the patient was more satisfied with the result of the operation (statistically significant $P < 0.02$).

The study reported in this article was un-

¹ The varus/valgus deviation of the knee is defined as the angle between the hip-knee line and the mid position of the knee-ankle line, i.e. the bisector of the medial-lateral angle of instability.

ANKLE FRACTURES

Supination-Eversion Fractures Stage II

Primary and Late Results of Operative and Non-Operative Treatment

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Sixty-nine patients with stage II supination-eversion fractures of the ankle, 34 treated by operation and 35 treated conservatively, were seen at follow-up after 3-10 years. There was no statistically significant difference

lateral malleolus in the anatomical position obtained by operation.

Key words ankle fractures, arthrosis, non-operative treatment, operative treatment, supination-eversion fractures stage II

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In most clinics the treatment of the various types of malleolar fractures is mainly non-operative, although for many years it has been considered expedient to perform osteosynthesis in some of the displaced posterior tibial fractures, unstable ruptures of the syndesmosis, and loose medial malleolar fractures (Müller 1945). During the past 15 years, however, ever increasing importance has been attached to the state of the lateral malleolus (Danis 1949, Willenegger 1961, Weber 1966, Cedell 1967) to which about 20 per cent of the body weight is transferred during the first phase of walking (Weber 1966). It has been demonstrated experimentally by Riede et al (1969) that a 2 mm displacement of the lateral malleolus may entail a talar displacement of 1-2 mm and 1-2 degrees of external rotation, reducing the articular surface contact between the tibia and talus by about 50 per cent. On this basis Riede et al concluded that any malleolar fracture uniting with displacement of the

lateral malleolus has a tendency to develop arthrosis due to incongruence after a varying length of time.

The ankle injury designated by N Lauge Hansen (1942) as a supination-eversion fracture stage II (SE II) is a pathologically well-defined (Figure 1) and common subgroup of ankle fractures (Cedell 1967).

In the present study the course of treatment and the late results (subjective, objective, and radiological) of operative and non-operative treatment of SEII injuries were compared.

PATIENTS AND METHODS

During the 8-year period 1968-1976 a total of 488 malleolar fractures were treated, primarily and after discharge, in the Department of Orthopaedic Surgery, Hjørring Hospital, Denmark, and 247 in the Department of Surgery, Frederikshavn Hospital, Denmark. The two series do not include patients under 15 years of age, epiphyseolyses,

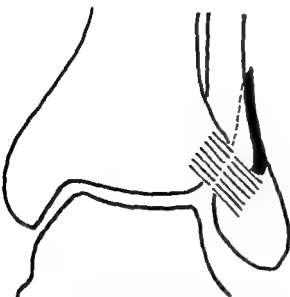


Figure 1 Supination-eversion fracture stage II
Rupture of the anterior tibiofibular ligament
(stage I) Distal oblique fibular fracture (stage II)

"pure" ligament injuries, or fractures caused by direct violence. The Lauge Hansen classification (1942) was used for typing and staging the fractures (Table 1). During the period all the SE II injuries in Frederikshavn were treated non-operatively.

During the winter of 1978-79, 34 operatively treated patients (Hjørring) and 35 non-operatively treated patients (Frederikshavn) were seen at follow-up. The reasons for the reduction in the number of patients making up the two materials can be seen in Table 2. The sex ratio

Table 1 Distribution of fracture types according to the classification of Lauge Hansen (1942)
Percentage

Fracture types	Hjørring n=488	Frederikshavn n=247
supination-adduction	20.1	18.6
supination-eversion		
stage II	33.2	35.2
III	2.3	3.3
IV	21.5	17.4
V-VI	0.4	0.4
	57.4	56.3
pronation-abduction/ pronation-eversion	20.9	21.1
other	1.6	4.0
	100.0	100.0

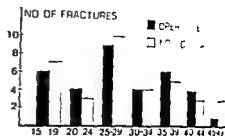


Figure 2 Age distribution

(males/females) for the operatively treated patients is 1.5.

Figure 2 main
7/8, "
"other
joint 1

The primary displacement according to the classification of Cedell (1967) is listed in Table 1.

Operative treatment (Hjørring)

Radiologically visible displacement of an SE II fracture was considered an indication for osteosynthesis. Relative contraindications were age over 49, unfavourable soft tissue conditions and fractures occurring more than 24 hours before admission. Other reasons for conservative treatment were the patient's wish not to undergo operation and the lack of operative capacity.

Six different surgeons did the operations which were performed in a bloodless field. The fracture was exposed by a slightly arcuate longitudinal incision over the lateral malleolus, accurately reduced, and fixed. Until 1974 the fixation was by steel wire cerclage (20 fractures, Figure 3) and after that time by small AO screws (12 fractures).

After the fracture was stabilized, the ligament was sutured. In addition the ligament was stabilized by the staple described by Cedell & Wiberg (1967). This elastic steel staple was hammered in parallel with the ligament. A suction drain was inserted and after a below the knee plaster cast had been applied the leg was kept elevated for about 3 days. In 26 patients the plaster cast was worn for about 6 weeks, in 11 patients in the form of a walking cast during the last 2 or 3 weeks. Since 1974 the plaster cast has been removed (7 patients) at the time of removal of the sutures on the 14th postoperative day, and the patients have commenced exercises, but weight-bearing has not been allowed.

Table 2 Criteria and reasons for exclusion of patients from the study of supination eversion injuries stage II

	Hjørring 160	Frederikshavn 87
Total SE II material		
Exclusion		
Age over 49	74	31
Not operated on because of		
local disease	2	0
late admission	4	0
lack of time and other reasons	31	0
Treatment completed elsewhere	4	5
Follow-up not practicable		
dead	4	1
systemic disease	1	0
new injury	0	3
remote domicile (> 50 km)	5	4
refused other reasons	1	8
Total excluded	126	52
Total seen at follow up	34	35

until about 6 weeks after the operation. At that time the cerclage and Wiberg staple were removed under general anaesthesia, whereas the small screws were left, unless they caused annoying prominence. Most recently, after the use of cerclage had been abandoned, the removal of the Wiberg staple has been on an outpatient basis with local anaesthesia.

The mean stay in hospital was 11.1 days (range 5-21 days).

Non-operative treatment (Frederikshavn)

All SE II fractures were treated non-operatively without reduction of the fracture. Primarily, the patients were admitted until the swelling subsided. Within the first 2 weeks a lower leg walking cast was applied and worn until 6-8 weeks after the trauma.

The mean stay in hospital was 5.7 days (range 1-10 days).

The materials were examined clinically and radiologically by the authors after a mean follow-up period, for both series, of 6.0 years with a range of 3-10 years.

RESULTS

1 Primary results

The radiological results of the reduction were recorded about 2 weeks after the treatment was started (Table 5). Within the operated group 84 per cent (28/34) obtained

Table 3 Occupational strain on ankle joint

Group	Occupation	Operative treatment	Non-operative treatment
1	unprotected, heavy fisherman, farmer, woodcutter, shipyard worker	8	7
2	unprotected factory worker, shopkeeper, cleaner (full time)	11	10
3	possibility of protection cleaner (part time), country housewife	6	2
4	little strain on legs housewife, teacher, student	5	16
		34	35



Figure 3 Fixation of the distal oblique fibular fracture by cerclage. The anterior tibiofibular ligament is sutured and strengthened by a staple

"anatomical" reduction, while 71.3 per cent (25/35) in the non-operatively treated group had a "poor" position according to the Cedell classification (1967). Whether the reduction

Table 4 Radiological degree of displacement before treatment (classification according to Cedell 1967)

Degree of displacement	Operative treatment	Non-operative treatment
Anatomical no displacement	1	0
Good slight rotation	7	8
Poor lateral and/or dorso- proximal displacement, marked rotation, valgus position	26	27
	34	35

Table 5 Radiological result of reductive & operative and conservative treatment (classification according to Cedell 1967)

	Operative treatment	Non-operative treatment
Anatomical	21	1
Good	5	9
Poor	1	25
Total	34	35

was effected by cerclage or by small wire does not seem to have affected the result (Table 6).

One operatively treated patient developed skin necrosis after removal of the cerclage wire and Wiberg staple. Healing took place within 6 weeks. One non-operatively treated patient developed a plaster pressure sore which left a chronic eczematized scar.

The period off work was recorded as exclusion of the patients in the group having work which causes least strain on the leg (Table 3, group 4). This period averaged 11 weeks in the operatively treated and 13 weeks in the non-operatively treated group.

2 Late results

The minimum follow-up period is 3 months. The subjective symptoms were classified according to Baek Kristensen (1953). According to Cedell (1967), the objective findings according to Baek Kristensen (1953), Cedell (1967) and Weber (1966).

Radiological changes of the joint were recorded according to the criteria of Magnusson (1944) and Weber (1966). Comparing the subjective and objective results, the classifications of Cedell were used, as they make the strictest demands.

Table 6 Radiological result of reductive & fibular fixation with cerclage or small wire (classification according to Cedell 1967)

	Cerclage	Small wire
Anatomical	17	17
Good	2	2
Poor	1	0
Total	20	19



Figure 4 Fixation of the distal oblique fibular fracture by a small AO screw

Subjective results (Table 7)

- (1) good The patient is completely symptom-free or rarely has quite negligible symptoms of pain, swelling, stiffness, or tiredness, but only after extra exertion
- (2) medium Moderate symptoms of pain, swelling, stiffness, or tiredness after exertion, but no reduced capacity for work and in most cases normal capacity for exercise and sports
- (3) poor Severe symptoms of pain, swelling, stiffness, or tiredness, especially on exertion, and as a rule reduced capacity for work

Within the operated group three of the four patients with moderate symptoms after exertion had an "anatomical" and one a

"good" result of the reduction. In two the complaints were apparently due to the scar and in the remaining two to the non-removed osteosynthesis material.

After non-operative treatment one patient complained of chronic eczema after a pressure sore, and two had mild symptoms of arthrosis ("poor" position of the fracture). In the remaining three patients there was no objective or radiological explanation for the symptoms.

Table 7 Late subjective results (classification according to Cedell 1967)

	Operative treatment	Non-operative treatment
Good	30	29
Medium	4	6
Poor	0	0
Total	34	35

Table 8 Classification of late objective results (+) increase, (-) decrease (modifications of Cedell's classification)

Components	Good	Medium	Poor
gait	normal	normal	long
size of the lower leg (+)	≤ 1 cm	$> 1-2$ cm	> 2 cm
calf size (-)	≤ 1 cm	$> 1-2$ cm	> 2 cm
ligament tenderness	none	slight	marked
dorsoplantar flexion (-)	$< 15^\circ$	$16-30^\circ$	$> 30^\circ$
pronation-supination (-)	$< 1/3$	$< 2/3$	$> 2/3$
pes transversus-planus	none	slight	marked

Objective results (Table 9) Cedell's classification was used, with minor modifications (Table 8). One of the operated patients had a moderately increased circumference of the lower leg. Among the four non-operatively treated patients with a "medium" result three had ligamentous tenderness and one a reduced calf circumference. Of these four patients three had moderate symptoms after exertion.

Radiological results (Table 10) The injured ankle joint - and the contralateral joint for comparison - were investigated radiologically. The examination included the oblique projection advocated by Bolin (1961) which best reproduces the fibular malleolar rotation and visualizes the joint between the fibula-malleolus and talus.

Neither group showed any changes in position as compared with the primary radiological result after the initial treatment. There was no instance of pseudarthrosis. Radiological signs of arthrosis were found in one of the operated patients who had a "good" result of reduction and no symptoms or signs and in four of the non-operatively treated patients all of whom had a "poor"

position of the fracture and two of them complaints on extra exertion.

The results of operative and non-operative treatment were subjected to a two-tailed statistical test by the Fisher exact test. The following test probabilities were: for subjective symptoms $P=0.71$, for findings $P=0.36$, radiological results $P=0.36$. As none of these P values is < 0.05 , there is no statistically significant difference between the results of the methods.

DISCUSSION

In a follow up study made to compare results of operative and non-operative treatment it is important that the materials should be well defined, especially with regard to the position and severity of the injuries. Several authors (Burwell & Charnley 1965, Cedell 1967, Maatz & Nonnemann 1973) have considered that the Lauge Hansen classification of types and stages affords so far the most accurate description of ankle fractures and is well suited for recording and assessment.

Table 10 Radiological arthrosis (fibula-talus) according to Nagarsund 1962

Table 9 Late objective results (classification according to Cedell 1967)

	Operative treatment	Non-operative treatment
Good	33	31
Medium	1	4
Poor	0	0
Total	34	35

	Operative treatment	Non-operative treatment
0	33	3
(+)	1	0
+	0	0
++	0	0
+++	0	1
Total	34	35

treatment of such injuries (Willenegger, 1961, Erbruggen & Willenegger 1973)

There is a satisfactory similarity between the sex ratio, the primary fracture displacement, and the follow-up period in the two materials. On the other hand, the occupational exertion on the ankle joint is greater in the operative than in the non-operatively treated group (cf Table 3). A minor inaccuracy in staging the SE fractures is the evaluation of whether the deltoid ligament is injured. In the non-operatively treated group the staging is based exclusively on clinical and radiological data, whereas in the operated group the operative finding is included as well. This is the reason why the non-operative group may erroneously include a few fractures of the type SE IV having injury of the deltoid ligament (Cedell 1967).

Comparison of the late results with Bæk Kristensen's analysis from 1953, after closed reduction by the principles of Lauge Hansen (1942), shows no difference. Muschter & Götz (1974) also showed that non-operatively treated SE II injuries have a "good prognosis". Cedell (1967), analysing 38 operatively treated SE II injuries after a minimum follow-up period of 5 years, found 16 to be subjectively "good", one "medium", and one "poor", objectively 31 "good", seven "medium", and none "poor". Only one patient had developed radiologically visible arthrosis.

Supination-eversion fracture in stage II is generally - and apparently rightly - considered a relatively benign injury which leaves few major permanent complaints. This contributes to the difficulty in demonstrating any differences in the results of the therapeutic methods. Larger series than the present ones and perhaps a longer observation time are presumably needed to decide whether the displacement of the lateral malleolus persisting after non-operative treatment affords the same possibility of free function of the ankle joint as open reduction obtaining union of the lateral malleolus in a radiologically accurate anatomical reduction.

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PROCEEDINGS OF THE FINNISH ORTHOPAEDIC ASSOCIATION

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EDITOR A. ALHO

ULTRASONIC WELDING OF EXPERIMENTAL OSTEOTOMIES

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Thirty-two scapular osteotomies were performed in rabbits. Ultrasonic osteosynthesis was carried out by applying a mixture of ethylcyanoacrylate liquid monomer and bone chips at two different sites in the osteotomy line and polymerizing it with ultrasound (URSK - 8V, Medexport, Moscow). Control osteotomies were fixed with steel wires. The stability of the osteotomies was tested manually and the stage of healing was estimated by radiographical and histological examination up to 8 weeks after surgery.

The results revealed that 41 per cent of the welded osteotomies (7/17) and 93 per cent of the controls (14/15) were stable. Histologically ultrasonic welding inhibited new bone formation and even after 8 weeks the osteotomies showed fibrous union. Inflammatory cell infiltration was moderate at the welding sites. By contrast, the controls had osseous union as early as 2 weeks after surgery.

In conclusion, the present study revealed that ultrasound as a method of osteosynthesis has marked disadvantages as regards bone healing.

TORSIONAL STRENGTH OF CORTICAL AND CANCELLOUS BONE GRAFTS AFTER RIGID PLATE FIXATION

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Biomechanical properties of cortical and cancellous interposition grafts in rabbit tibiofibular bones fixed with 6-hole DCP/ASIF plates were investigated with torsional loading 3 to 52 weeks postoperatively.

In cortical grafts, torque, energy absorption and

weeks, of the torque and energy absorption capacity of the cancellous grafts.

From 12 to 52 weeks the values of the biomechanical properties of both graft types decreased. At 36 weeks the mean values of torque, energy absorption, torsional rigidity and angle deformation for cortical grafts were 39, 34, 57 and 82 per cent of the control bones, and those for the cancellous grafts were 26, 17, 42 and 58 per cent, respectively.

REVASCULARIZATION OF PERIOSTEAL GRAFTS

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Acta orthop. scand 51, 197-204

EXPERIMENTAL GROWTH DISTURBANCE OF THE ACETABULUM AND DISLOCATION OF THE HIP

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The aim of this study was to clarify the role of dysplastic acetabular growth disturbance in the development of experimental subluxation or dislocation of the hip.

Acetabular growth disturbance was provoked operatively in 3-week-old growing rabbits by performing a wedge resection extra-articularly in the acetabular roof. The growth of the hip was observed at regular intervals. During the follow-up, a disturbance of acetabular growth was noted

which later led to a dislocation or subluxation with typical secondary changes

From these preliminary studies, it appears that acetabular growth disturbances could be induced repeatedly with the method applied

SKELETAL BLOOD FLOW IN THE RABBIT MEASURED WITH RADIOACTIVE MICROSPHERES

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The distribution of cardiac output was measured in 14 adult white New Zealand rabbits. Radioactive microspheres were introduced into the arterial circulation by a left ventricular injection. The skeleton was removed from the carcass after boiling in a pressure cooker and the activities were measured. The proportion of the cardiac output distributed in the skeleton averaged 5.64 per cent, SD 0.96 per cent.

In 10 rabbits a diaphyseal tibia osteotomy was performed and stabilized by external fixation. The proportion of the cardiac output found in the intact tibia was 0.12 per cent, SD 0.07 per cent. The circulation in the osteotomized tibia as compared with the intact bone from the 6th to 30th postoperative day was significantly higher, 0.21 per cent, SD 0.09 per cent ($P < 0.01$). Autoradiography and histology revealed that most of the injected particles present at the osteotomy site were in the endosteal callus, indicating centrifugal blood flow in the tibia after osteotomy.

PERIOSTEAL AND PERICHONDRAL GRAFTS IN RECONSTRUCTION OF THE PATELLAR JOINT SURFACE

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In our original studies (*IRCS Medical Science* 3: 49-50, 1975) we utilized perichondral as well as periosteal grafts to restore experimental cartilage defects of the knee joint. We have now applied our method to the reconstruction of the patellar cartilage in three patients. The graft was taken from the periosteum of the tibia or the perichondrium of the costal cartilage. Two of the patients were females 16 and 35 years old, and one patient was a 28-year-old male. All had sustained severe chondral injuries. Postoperatively the patients were followed up for more than a year. All improved subjectively. Arthroscopy

visualized a smooth patellar surface and biopsy of the grafted area revealed hyaline cartilage. We conclude that free periosteal and perichondral grafts maintain their vitality and form cartilage and bone. The grafts retain part of their extracellular message but they can also adapt to environmental factors as undifferentiated tissues.

FACTORS INFLUENCING THE RESULTS OF OPERATIVE FUSION OF THE LUMBO-SACRAL SPINE

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One hundred and two patients out of a total of 119 were accepted for the study after a radiologically successful posterior fusion of the lumbar spine. The follow-up period was on average 4.8 years. Data obtained from the patients' records and from questionnaires relating to social factors were subjected to a multiple regression analysis (*Acta orthop scand* 48: 415-425, 1979).

The factors that had a statistically significant and independent effect on the operative result may be summarized as follows. The operative results improved with decreasing duration of preoperative disability, with increasing number of fused segments, with decreasing strenuousness of preoperative work, with rising social position, with rising educational level and with decreasing number of previous back operations. Age had no significant effect on the operative result. In conclusion, vocational and other social factors should be considered before subjecting the patient to operation.

TREATMENT OF LUMBAR SPONDYLOLISTHESIS IN YOUNG PATIENTS USING FREE OSTEOPERIOSTEAL GRAFTS

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Our experimental and clinical studies have shown that free periosteal grafts under the proper circumstances possess great bone-forming capacity. Solid fusion of the lumbar spine of the rabbit can be achieved using this method. Fusion of the scoliotic spine with osteoperiosteal grafts in connection with the Harrington method has also proved successful.

Thirty-six young patients with spondylo-

of the patients the slipping was more than one third of the vertebral body. Posterior fusion was carried out in 20, posterolateral in 8, and fusion and laminectomy in 8 patients. Fusion of the affected segment was obtained in 31 patients. Twenty-five patients were symptom-free post-operatively, five patients had some low back pain after exercise and six patients had radiating pain. Follow-up time varied from 1 to 4 years.

PRELIMINARY RESULTS OF 100 LUBINUS PROSTHESES IN TOTAL HIP REPLACEMENT

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Sixty-six women and 34 men were operated on. The indication for the total hip replacement was primary osteoarthritis - 57, secondary osteoarthritis - 18, and rheumatoid arthritis - 25. Fourteen hips had been operated on earlier. Follow-up time varied from 1½ to 2½ years.

The evaluation of the radiographic severity was made according to Rönningén & Langeland (*Acta orthop scand* 50: 169-174, 1979). The index sum was on average 11.7 in the II° group (30 hips) and 14.9 in the III° group (70 hips).

The patient's own opinion of the result was good in 71, satisfactory in 27 and poor in 2 hips, the opinion of the authors gave figures of 83, 15 and 2, respectively. There were no infections, one early dislocation, one femoral stem loosening, one avulsion of the lesser trochanter, early signs of resorption of the stump of the femoral neck (less than 3 mm) in 6 hips and ectopic bone formation in 19 hips (with no clinical symptoms).

SECONDARY HYPERALDOSTERONISM AFTER SEVERE TRAUMA

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Ten patients being treated in the intensive care unit were studied for changes in plasma aldosterone concentrations during an 8-day period after a major injury. Eight of the patients had sustained a blunt injury and two had a burn trauma. The average amount of fluid replacement during the first 24 hours amounted to 6273 ± 3523 ml. Three patients died.

An increase in plasma aldosterone was consistently found after trauma. Peak values, 253.3 ± 196.0 ng/l were registered immediately

after admission to the hospital. The aldosterone concentrations then fell to 180.0 ± 193.0 ng/l on the first day and 97.2 ± 73.8 ng/l on the second day after the trauma. The reaction subsided within 3 days and subsequently the aldosterone concentrations remained within normal limits.

High initial aldosterone values were recorded especially in the burn cases. There was no sign of persistent secondary hyperaldosteronism. Sodium depletion, however, caused a transitory increase in the aldosterone level in one case.

THE RICHARDS COMPRESSION SLIDING NAIL IN FRACTURES OF THE PROXIMAL END OF FEMUR

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From April 1978 to June 1979, 46 patients (mean age 67 years) were treated with the Richards compression sliding nail. The fractures were subcapital - 4, transcervical - 8, intertrochanteric - 10, and pertrochanteric - 24.

During the 7-month follow-up period, change of position was observed in three neck fractures, and three pseudarthroses ensued. However, there was not a single change of position or non-union among the pertrochanteric fractures, although nine of these patients subjected their extremity to full weight-bearing within 10 days.

Bony union ensued within 1 month in 12 cases, in 2-4 months in 24, and in 4-6 months in 10.

One patient developed a deep infection, which responded to antibiotics. The causes of three postoperative deaths were myocardial infarction, cerebral thrombosis and pneumonia. The frequency of complications was higher ($P < 0.001$) in the subseries of patients treated surgically more than 3 days after trauma, compared with those whose operation took place within 3 days.

THE RYDELL OSTEOSYNTHESIS IN THE TREATMENT OF FEMORAL NECK FRACTURES

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Since 1972, the Rydell osteosynthesis, described in 1961, has been performed in 31 cases (14 men, average age 55.3 years, 17 women, average age

71 3 years) The result was good in 15 out of 17 cases with Garden stage I and II fractures. Poor results were found in 8 out of 14 cases with stage III and IV fractures.

Osteonecrosis of the femoral head was found in four cases. Two post-operative femoral neck dislocations occurred due to operative errors. One patient complained of marked postoperative stiffness of the hip. In one case a subcapital refracture was observed 9 months postoperatively. One patient developed pseudarthrosis and one died three weeks postoperatively because of pulmonary embolism.

During the last 3 years the Rydell nail has been used only in undislocated and minimally dislocated femoral neck fractures. The internal fixation pin seems to exclude sliding, without disturbance to the impaction of the fracture during loading.

PROGNOSIS OF PATIENTS WITH FEMORAL NECK FRACTURE

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The ability to cope socially was studied with the aid of interviews, 3 to 5 years after the trauma, in 54 patients operated on for femoral neck or trochanteric fracture, in 50 patients not yet operated at the time of the interview and having fractures in the same locations, and in 48 control subjects of the same age. The groups did not differ in terms of marital status, education, state of health, and leisure activities.

Prior to the injury, the social adaptation of the non-operated patients was either slightly ($P < 0.025$) or markedly ($P < 0.0025$) reduced when compared with the controls, and they had to be helped in all activities more often than the operated patients ($P < 0.025$) or the controls ($P < 0.05$). The patients not yet operated on were less able to cope in their daily activities than were the controls ($P < 0.005$). At follow-up 24 per cent of the operated patients and 10 per cent of the control persons lived in nursing homes and hospitals. Twenty-four per cent of the non-operated patients lived in similar institutions at the time of the injury. The mortality during the follow-up time was 50 per cent. In conclusion, it can be stated that the ability of patients with femoral neck and trochanteric fractures to cope socially is reduced.

CORRELATION BETWEEN RADIOLOGICAL

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A total of 313 out of 460 patients with spine injuries were followed up for an average of 3 years and 3 months. The distribution of the injuries was as follows: C1-C7, 119; Th1-Th11, 112; Th12-L1, 149; and L2-L5, 94. Flexion, lateral angulatory deformity, compression, narrowing of the vertebral canal, increase in interpediculate distance, increase in vertebral body distance and lowering of the disc space were examined radiologically.

During the follow-up the forward sliding and narrowing of the vertebral canal in the cervical spine were reduced to a marked extent. The other radiological deformities showed a tendency to deteriorate. Narrowing of the vertebral canal and forward sliding were most often associated with neurological symptoms. The clinical results of the thoracolumbar and lumbar segments seemed to a great extent to depend on the findings on the first radiographs. In cervical spinal injuries poor clinical results were noted in connection with persisting radiological deformities.

In the patients with cervical spinal injury the goal of the treatment should be to achieve an anatomical result. The present investigation does not permit any confident conclusion with regard to the usefulness of correcting deformities in the cervical spine.

ARTHROGRAPHY IN THE DIAGNOSIS OF LIGAMENT INJURIES OF THE ANKLE

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During 1970-1978, 120 lateral ligament injuries of the ankle were diagnosed by arthrography and operatively treated in the Oulu University Central Hospital. In 50 ankles there was a isolated rupture of the anterior fibulotalar (FTL) ligament and in 60 ankles a combined injury of the FTL and the fibulocalcaneal (FC) ligament. An isolated rupture of the FC ligament was found in 10 ankles. The arthrographic diagnosis was correct in 109 of the 110 cases of FTL rupture (99 per cent). The typical X-ray finding was the contrast medium out of the joint space on the lateral side of the lateral malleolus.

arthrography on the basis of spread into the peroneal tendon sheaths. Furthermore the rupture was suspected in five cases in which there was noticeable spread at the calcaneal insertion of the TC ligament. Thus the X-ray diagnosis was correct in 87 per cent of these injuries. There were no cases of pathological findings in arthrography without a ligament rupture.

CORRECTIVE OSTEOTOMY OF TRAUMATIC HUMERUS VARUS

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Postfractural varus deformity of the humeral neck was treated with high corrective osteotomy of the humerus in seven adult patients (four males and three females). The average age was 41 years. All had been subject to high energy trauma. Indications for operative treatment were severely limited abduction (under 60°) and forward flexion of the arm. Wedge osteotomy was performed through a deltopectoral incision and fixation was with a T-formed AO-plate, on average 11 months after the injury. The follow-up time varied from 6 months to 11 years.

Six patients regained complete or almost complete painless motion. In the remaining case the result was only "satisfactory" because of frozen shoulder severe muscle atrophy and poor motivation for recovery. Thus correction of varus and rotational deformity appears to be a useful method in cases where the glenohumeral joint is not damaged and the soft tissue contractures are not severe.

FRACTURES OF THE CARPAL SCAPHOID IN CHILDREN

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One hundred and eight children with carpal scaphoid fractures were followed until radiological fusion occurred. All fractures united during conservative treatment. The locations of the fractures were: distal third - 87 per cent (avulsions - 38 per cent), waist - 12 per cent, and proximal pole - 1 per cent. The large number of avulsion fractures and the location of the fractures in the distal third of the scaphoid were typical for

children. In three neglected cases of waist fracture large bone resorption occurred on the fracture surfaces, but conservative treatment started in two cases at 3 weeks, and in one case at 3 months, resulted in fusion. Generally an immobilization time of 4-8 weeks in the classical plaster cast was enough, but in neglected cases and in cases with major bone resorption a longer period of immobilization, up to 16 weeks, was needed.

DIAGNOSIS AND TREATMENT OF ACUTE DISLOCATION OF THE PATELLA

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To be published.

INJURIES OF COMPETITION SKIERS IN FINLAND A THREE-YEAR SURVEY

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This epidemiological study was performed in 1976-1978 in cooperation with the Pohjois Insurance Company and the Finnish Skiing Association.

The total number of licenced competition skiers in Finland in 1978 amounted to 7,814, 7,032 participating in cross-country skiing, 275 in ski jump and 487 in downhill events. During the 3-year period a total of 180 serious accidents were registered. Ski jumpers had 39 injuries and the risk of injury was highly significantly ($P < 0.001$) greater than in downhill events (27 injuries) or cross-country (57 injuries). Fractures and luxations predominated in both ski jump and downhill events, muscle and tendon injuries were the largest group in cross-country. With ski jumpers the injury was predominantly located in the head or neck, while lower extremity trauma was more common in cross-country and downhill skiers. The risk of malleolar injuries was highest in ski jumping while downhill skiers had more knee injuries. Twenty-five per cent of the injuries were fractures and 18 per cent of the patients had operative treatment. Ski jumpers required four times more sick leave days than those in downhill events and ten times more than cross-country skiers.

TIBIAL OSTEOTOMY, A FIVE TO TEN YEAR FOLLOW-UP STUDY

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Between January 1969 and June 1974 145 knees in 135 patients were operated on because of osteoarthritis of the knee. A wedge osteotomy was used in all cases. Ninety-six of the 116 patients still alive (105 knees) were seen at the follow-up examination in 1979. The average postoperative follow-up time was 7 years with a minimum of 5 years. All osteotomies united without reoperation. In 89 knees (84.7 per cent) the initial result was good or fair. Best results in cases of varus deformity were achieved with a 7° overcorrection and in valgus deformity when the femorotibial angle was corrected to 171°–178°. Deterioration was noted in 26 cases after an initially good result, this seems to be a higher rate than earlier described. In 16 knees total arthroplasty was indicated because of a poor result. In 15 of the 19 knees with preoperative instability the result was good or fair. All five knees with initial subluxation less than 12 mm became good or fair after osteotomy. Thus, instability and minor subluxation are not, according to this study, obvious contraindications for osteotomy.

XANTHOMAS OF THE ACHILLES TENDON

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Two patients had bilateral xanthomas in the Achilles tendons associated with type II hyperbetalipoproteinaemia inherited as an autosomal dominant. Both patients had elevated serum cholesterol normal or slightly elevated serum triglycerides and an electrophoretic pattern of elevated beta lipoproteins. Subtotal resection of the tumours was found to be satisfactory in both patients. The alternative is total excision and reconstruction of the defect with fascial grafts. The surgical interventions for the tendon

metabolism
- medical lipid

The early recognition and evaluation of patients with hyperbetalipoproteinaemia is important because of an increased incidence of atheromatous coronary heart disease, manifesting at an early age.

PRIMARY MALIGNANT FIBROUS HISTIOCYTOMA OF BONE

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A review of 869 malignant primary bone tumours yielded nine lesions with fibrous histiocytoma. Correlation with clinical data and roentgenograms indicated that these tumours occurred as osteolytic lesions associated with pathological fractures in metaphyses of long bones. Five patients received ablative radical surgery, two patients were not given any local treatment, one was given radiation treatment and one chemotherapy for their tumours. Two patients had pulmonary metastases and one had metastases in the lymph nodes. The mean survival period was 17 years and the 5-year survival was 22 per cent. Six patients underwent surgery, chemotherapy or radiation therapy to their metastases. Primary malignant fibrous histiocytoma of bone is a very malignant tumour and treatment should be the same as for osteosarcoma. Radiation and chemotherapy are recommended. The differential diagnosis is with osteolytic osteosarcoma and fibrosarcoma.

EXPOSED KNEE JOINT IN AVULSION INJURIES OF THE LOWER EXTREMITY

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Two cases are reported in which the exposed knee joint was covered with well-vascularized tissues. In the first case a medial gastrocnemius myocutaneous flap was used to cover the knee joint. The cutaneous part of the flap extended over the avulsed patella and patellar ligament. The donor area of the flap and the degloving injury of the thigh were covered with meshed split skin grafts. In the second case a lateral gastrocnemius muscle flap was covered with the transposed muscle was covered with split skin grafts. The primarily covered knee joint healed without complications. The muscle myocutaneous flap forms well-vascularized tissue over the joint, and later it is easy to move the joint for further reconstruction.

THE USE OF RADIOISOTOPE BONE SCANNING IN DISEASES OF THE FACIAL BONES

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The observations in 50 patients were as follows - In primary gingival cancer the bone image appears larger than in normal radiography - In lung and breast cancer patients unexpected metastases in the mandible may be found. - All inflammatory processes markedly increase the

radioisotope uptake in the mandible as in all bones. This is especially valuable in primary chronic osteomyelitis. - Fibrous dysplasia results in highly increased isotope uptake instead of monostotic dysplasia, tetrastotic dysplasia may be seen in the bone scan - Growth disturbances in the condylar head may be detected in hemimandibular hypertrophy of unilateral hyperplasia of the condylar head - Increased uptake is also seen in eosinophilic granuloma, dentigerous cyst and active arthrosis of the temporomandibular joint

SYMMETRIC BIPHASIC VOLTAGE STIMULATION OF THE OSTEOTOMIZED RABBIT BONE

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An experimental study was performed to determine the effect of electric current on the healing of osteotomies in the antebrachium of the rabbit. Starting with the assumption that the waveform of biphasic asymmetric voltage simulates the asymmetric pattern of stress induced physiological electrical potentials in normal bone, biphasic asymmetric voltage was applied to the osteotomized radius or ulna. The effects of the electrical stimulation were evaluated by means of X rays and histological studies. The voltage supplied induced periosteal proliferation whether implanted, insulated electrodes were employed or uninsulated external transfixation pins were used as electrodes. The stimulation had not only osteogenic but also chondrogenic effect. The external callus formation at the osteotomy sites and around the transfixation pins proved to be greater in the stimulated animals than in the controls.

Key words chondrogenesis, electrical stimulation, fracture healing, osteogenesis.

Accepted 3 in 80

The occurrence of mechanically induced electrical potentials in bone (Fukada & Yasuda 1957, Cochran et al 1968) may play an important part in the regulation of fracture healing and bone remodelling, and in the prevention of osteoporosis. Furthermore, osteogenic effects can be produced in bone by application of different types of electric currents: constant direct current (Friedenberg et al 1970), pulsed direct current (Levy & Lubin 1972) and alternating current (Klapper & Stellard 1974). Electricity has been applied to bone using an invasive technique, in which electrodes are implanted into bone (Friedenberg et al 1970) or using a non-invasive technique, in which case stimulating current is induced in bone electromagnetically (Bassett et al 1974).

Despite intensive work during the last two decades the most efficient form of electricity

for this purpose remains undiscovered (Brighton 1977). Hassler et al (1977) have shown a correlation between healing quality and power dissipation when direct current and alternating currents were applied. The significance of asymmetry in voltage waveform emphasized by Bassett et al (1977) was not studied however.

Since mechanical stress during walking generates asymmetric, intermittent and bidirectional potentials in bone (Cochran 1974), it seems reasonable that asymmetric alternating current or voltage should be active in stimulating osteogenesis. Only Bassett (1971) has reported some preliminary results of the use of asymmetric alternating current, i.e. an alternating current containing a direct current component. He noticed, for example, that an asymmetric alternating current increased osteogenesis at the cathode, while

symmetric alternating current did not result in increased new bone formation at either electrode. Jørgensen (1972, 1977) has reported promising clinical experience with the use of a slow pulsating, asymmetric direct current stimulation in human crural fractures, yet the shortage of experimental studies has hampered the evaluation of the results.

On the basis of the information given above we started to investigate the effects of stimulation with asymmetric biphasic voltage (i.e. a direct current containing bipolar alternating current pulses) using osteotomized rabbit bones. We also tried to develop a standardized experimental fracture with external transfixation for the evaluation of the effectiveness of electrical stimulation on bone repair.

MATERIALS AND METHODS

Animals and surgical techniques

Sixteen mature rabbits, weighing from 2.5 to 3.6 kg, were operated on under intravenous pentobarbitone sodium (Nembutal[®], Abbot) anaesthesia. Surgical sterility was maintained.

Radius series

In the radius series of five rabbits the distal shaft of the bone was exposed and a 2 mm transverse osteotomy was made using an oscillating saw. Two holes 10 mm in diameter were drilled in the cortex using a dentist's drill. The holes, which penetrated into the medullary cavity, were placed one proximal and one distal to the osteotomy at a distance of 5 mm. Ten per cent indurized platinum electrodes (0.5 mm) insulated with teflon (Alu Oy, Finland) were used. The bone electrode was fixed with the aid of chromic catgut into the distal hole of the radius so that the bent uninsulated 2 mm long tip of the electrode extended from the periosteum to the medullary cavity (invasive technique). The second electrode was fixed with chromic catgut to the soft tissue close to the osteotomy gap. The electrodes ran subcutaneously to the shoulder region to emerge from the skin. The emerging parts of the electrodes were covered with a silicone rubber tube to prevent skin irritation. The electrodes were connected to the insulated copper leads from the stimulator by the detachable connector which was fixed to the leather harness of

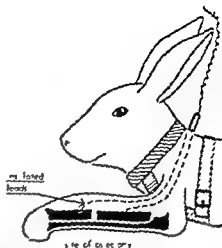


Figure 1 Diagram of the implanted radii electrode leads in relation to the osteotomy in the rabbit radius

the rabbit. The stimulator was placed on top of a wire mesh cage (Figure 1).

Ulna series

An external transcutaneous fixation method was used in the ulna series of five rabbits. This method made it possible to combine the electrostimulation and the immobilization procedure (non-invasive technique). The ulna was used for practical reasons. The osteotomy was easier to perform due to the greater diameter of the bone and use of the ulna made an external transfixation possible. A transverse osteotomy was made in the proximal shaft of the ulna. The operation was



Figure 2 Illustration of the postoperative appearance of the osteotomized radius stabilized with two Kirscher pins, etc. as used as electrodes

ansfixed by two parallel Kirschner pins 1.2 mm in diameter. The pins were inserted transcutaneously above and below the site of the osteotomy and fastened together by metal plates insulated with rubber. The pins, left uninsulated in bone and soft tissues, were used as electrodes. Lead connections to the stimulator were similar to those of the radius series.

Control series

Identical surgical procedures and fixations were performed in the control series of six rabbits but the electrodes were not connected to the stimulator.

Electrical stimulator

The voltage supplied was selected on the basis of previous knowledge.

1 The voltage waveform recorded on the surface of a dog's radius in a walking simulator as potentials of unequal amplitude and opposite polarity (Cochran 1974).

2 The optimal frequency is about 0.7 Hz which corresponds to normal walking frequency (Levy 1971).

3 The voltage supplied should be limited to 1 V to avoid undesirable electrochemical reactions in tissues near the electrodes.

The desired biphasic asymmetric voltage waveform was achieved by a battery operated transistorized oscillator delivering both direct current and alternating current (Kone Oy, Instrument Division, Finland).

The voltage diagrams are shown in Figure 3. Bipolar rectangular alternating current pulses of amplitude 100 mV, pulse duration 8 ms,

frequency 0.8 Hz) were combined with the constant direct current level, which was 300 mV in the radius series and 100 mV in the ulna series. The currents measured during stimulation had both positive peaks (+22 μ A in the radius series and +100 μ A in the ulna series) and negative peaks (-18 μ A in the radius series and -100 μ A in the ulna series). The polarity was kept constant throughout the stimulation in the radius series. In the ulna series the polarity was reversed every 2 days.

Evaluation methods

After 14 days for the radius series and after 21 days for the ulna series the rabbits were killed by an overdose of pentobarbitone sodium. X-ray examinations were performed after killing. Bone samples were dissected taking the ulna and the radius together to avoid damaging the fracture area. The samples were fixed in 10 per cent buffered formalin, decalcified in New Decalc (Histo-Lab Sweden) and embedded in paraffin. Longitudinal sections were stained with haematoxylin and eosin, van Gieson, Alcian blue and periodic acid Schiff.

RESULTS

General observations The rabbits tolerated the experiment satisfactorily. The stimulated as well as the control animals lost an equal amount of weight, 200–600 g, during the experiment. Three rabbits were excluded from the material owing to wound/pin infection or splintage of bone fragments. The subcutaneously implanted anode leads in the radius series caused soft tissue irritation. Histologically the inflammatory cell infiltration was moderate or abundant around the anode leads.

Radius series

Macroscopically the periosteal callus in the stimulated animals was observed to extend from the osteotomy site to the midshaft of the radius, in the controls, however, the callus formation was limited to the osteotomy area only.

X-ray studies (Figures 4 and 5) revealed a

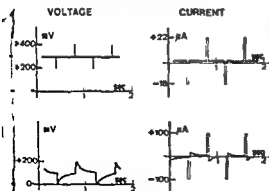


Figure 3 The voltage and current diagrams between electrodes in the radius (top) and ulna (bottom) series.

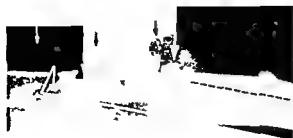


Figure 4 Anterior X-ray picture of an electrically stimulated osteotomy in the radius 2 weeks after operation. Marked fibrous callus extends from the osteotomy site to the midshaft (small arrows) of the bone. Calcified callus occurring midshaft and at the osteotomy gap indicated with large arrows. Solid white line=position of bone electrode. Interrupted black line=position of electrode in soft tissue ($\times 17$).



Figure 5 Anterior X-ray picture of the osteotomy in the control radius 2 weeks after operation. Slight callus visible at the end of the bone fragment (arrow). Σ =bone electrode. Interrupted black line=position of electrode in soft tissue ($\times 17$).

periosteal reaction along the shaft of the stimulated radius, but osteotomies showed no signs of bony consolidation in any of the animals.

Histologically the periosteum of the stimulated radius showed marked osteogenic reaction which extended from the osteotomy to the proximal part of the radius. The periosteal reaction consisted of new bone formation but also included cartilaginous areas (Figure 6B). The controls had minimal periosteal new bone formation in the



Figure 6 Periosteal reaction in the shaft of the radius in a control animal (A) and in an electrically stimulated animal (B). New bone formation (NB) and cartilage formation (C) are prominent in the stimulated animal ($\times 40$).

midshaft of the radius (Figure 6A). The endosteum showed only slight bone formation along the shaft of the stimulated radius. In the controls the endosteal new bone formation was found only at the osteotomy site being however greater than in the stimulated animals. The osteotomies of the stimulated animals had well defined external callus consisting of new bone and

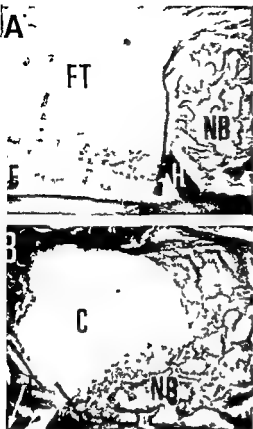
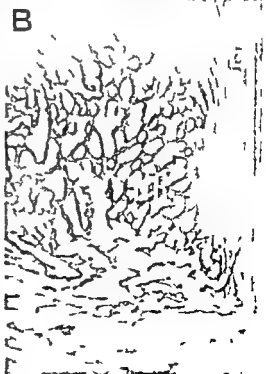


Figure 7 The osteotomy areas of the radius in a control animal (A) and in a animal electrically

stimulated (B). New bone (NB) is seen only in the periosteum some distance from the fracture gap (F) where fibrous tissue (FT) and a clot (H) are seen ($\times 15$)

Figure 8 New bone formation around the electrode pins (E) in a control ulna (A) and in a stimulated ulna (B) 21 days after electrical stimulation. Only weak new bone formation (NB) is seen in the control ulna whereas in the stimulated ulna the electrode pin (E) is surrounded by marked periosteal new bone (NB). The direction of the fixation pins (E) is illustrated by a solid line ($\times 15$)



cartilage (Figure 7B). In the controls the external callus consisted of fibrous tissue at the osteotomy sites and new bone was present some distance away from the osteotomy site (Figure 7A).

Ulna series

Macroscopically the electrode pins were found to be surrounded by periosteal callus in all animals and the reaction extended to the osteotomy site. In the stimulated animals the observed callus was more distinct.

X-ray studies showed that none of the osteotomies had bony uniting callus. A slight periosteal reaction around the pins seemed typical as well.

Histologically the most distinct change was to be seen in the periosteum. The electrode pins were surrounded by periosteal new bone and the reaction proved to be more pronounced in the stimulated than in the control ulnas (Figure 8A and 8B). The periosteal response consisted of new bone but also contained cartilaginous areas in some of the stimulated animals. The electrode pins were also surrounded by endosteal new bone in the stimulated animals. The controls had only thin trabeculae of new bone around the pins in the medullary cavity. All the osteotomies had fibrous union. However, the periosteal new bone formation between the osteotomy site and the electrode pins was more pronounced in the stimulated ulnas.

DISCUSSION

The results of this study of bone regeneration in the antebrachium using asymmetric biphasic voltage stimulation were found to be beneficial and encouraging. It was observed that the periosteal bone and cartilage formation was greater in the stimulated than in the control animals. The small number of animals does not, however, allow any statistical analysis. It is probable that the

optimal method of inducing osseous repair by means of artificially produced voltages is to simulate naturally occurring electrical events in bone. Mechanical stress induces a biphasic voltage waveform in bone (Bassett 1977) which is asymmetric under physiological conditions (weight-bearing) (Cochran 1977). Bone stimulation by means of a biphasic asymmetric voltage might simulate the voltage waveform artificially and come more closely to the physiological events in bone than stimulation by means of a direct current, a pulsed current or an alternating current.

It is generally accepted that osseous repair is promoted only around the cathode (Bassett 1977). In our study the polarity was changed every 2 days (the ulna series) and accelerated new bone formation was noted locally around both the electrodes. When the polarity was not changed during stimulation (the radius series), electrical stimulation promoted a periosteal reaction similar to that observed by Connolly et al. (1977). This was a necessary periosteal reaction can be produced due to the irritating effect of the electrode mechanism by which positive polarity produces tissue irritation (Jorgensen 1972, Englund et al. 1975) is unknown, but the irritation can be avoided if the polarity is reversed every 24–48 hours of stimulation (Jorgensen 1977). The results of our ulna series confirm this observation.

The voltage supplied seemed to affect particularly the cambium layer cells and so much those lining the endosteal surface of the cortical bone. The stimulation caused the development of an external callus that crossed the osteotomy gap, yet it was the control osteotomies that showed a tendency to be filled predominantly by medullary callus in the radius series. It should be noted that weight-bearing did not significantly effect the repair of the osteotomies, because the other series contained unstimulated bone of the antebrachium and a splint. The reason for the difference in the effect of electrical stimulation is observed in Rubin (1972) have previously reported the same phenomenon when pulsed current was

with a peak current of 500 μ A or more is applied. The prevailing opinion is that a common factor in cartilage formation is a low oxygen tension (Bassett & Herrmann 1961). It can be assumed that the periosteal outgrowth of its blood supply in the immobilized animals and cartilage formation is therefore more prominent in the stimulated ones than in the controls owing to decreased oxygen tension. Further studies by the authors (Aro et al 1979), on the other hand, have revealed that electrical stimulation increases oxygen tension in the fracture area.

In fact there can be several possible mechanisms by which electric current influences cell behaviour (Bassett et al 1977). As it is desirable in clinical work to avoid opening the fracture area because of the risk of contamination, we set out to study the possibilities of a less invasive method than one with separate implanted electrodes in the fracture area. The study showed that immobilization pins for long bone fractures can also be used as electrodes instead of local electrode leads. This observation confirms the clinical reports on the combination of electrical stimulation and external transfixation (Jorgensen 1972, 1977, Inoue et al 1977, Satzger & Herbst 1976). We have since further improved the external transfixation method by increasing the number of pins. This improved immobilization technique with greater stability has been found applicable to the immobilization of a tibial osteotomy in the rabbit (Aho et al 1978). This experimental fracture model combined with electrical stimulation is in principle analogous to the clinical application of electrical stimulation when bone rods of the Hoffmann apparatus are used as electrodes in human tibial fractures (Jorgensen 1972, 1977).

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THE FORMATION OF STRESS BY ACRYLIC BONE CEMENTS DURING FIXATION OF THE ACETABULAR PROSTHESIS

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The forces developed by acrylic cement during the final phase of polymerization under conditions that simulate the cementing of the acetabular prosthesis are evaluated. Calculations show that forces of 500-1100 N may be reached in a three-point fixational system. The importance of the dimensions of the plastic and the bone and the relevance of the E-moduli are discussed.

Key words: bone cement, hip joint prosthesis

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The use of acrylic compounds as a means of fixation of total hip prostheses is a commonly accepted procedure. During polymerization the acrylic compound undergoes certain changes in physical properties as it passes from semi-liquid to solid. These changes include a change in volume, a change in temperature, and a change in viscosity. The commercially available cements differ somewhat in handling characteristics and as shown by various investigators (Ohnsorge & Grotz 1974, Debrunner et al 1976, Holm 1977) they also vary as to certain physical properties. It was therefore found to be of interest to investigate further the behaviour of the most commonly used acrylic cements in order to increase the understanding of the nature of these substances. It is a well known fact that methylmethacrylate reduces in volume when polymerizing, the cement contracts. If this takes place in a situation where the contraction is hindered stress will arise. In the present experiment the behaviour of the acrylic cement during insertion of an acetabular component is investigated under conditions that imitate the actual situation.

MATERIAL AND METHODS

Design of the apparatus

In order to evaluate the build up of stress in the cement during polymerization under conditions that imitate conditions in the acetabulum an apparatus was designed and constructed. The most commonly used surgical procedure when preparing the acetabulum includes the drilling or gouging of three or more holes in the acetabular wall in order to give the acrylic cement good points of purchase in the bone. The apparatus (Figure 1) consists of a U-shaped heavy steel bar with a measuring device attached. The measuring device consists of a pin that passes through a hole in one branch of the "U" to the other. The pin moves a lever which can be coupled to a transducer or a dial gauge. Thus any change in the distance between the branches of the U-bar can be measured. The U-bar was dimensioned such that the contraction arising from the polymerization of the cement caused changes in the distance between the branches of the order of magnitude of 100 μ . Calibration showed the manufacturer. As soon as it could be handled the dough was pressed manually into a mould on top

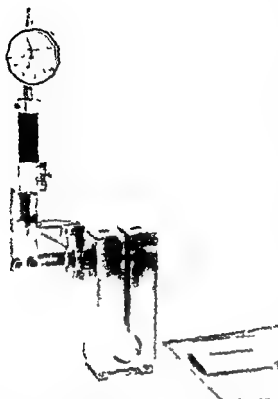


Figure 1 Apparatus for measuring cement shrinkage, mounted with dial gauge. Note dovetail grooves with adjustable width on the top of the branches. The mould is shown on the side.

of the U-bar where it would gain purchase in two dovetail grooves. The mould ensured the correct thickness of the sample and it was removed while the cement was still in the doughy state. The experiment thus consisted of a square block of cement on top of the U-bar, fixed in dovetail grooves and contracting freely (Figure 1). The whole assembly was placed in a waterbath at 38°C and all measurements were made at body temperature. Samples with the dimensions $20 \times 8 \text{ mm}$ and $20 \times 4 \text{ mm}$ in cross-section of each of the types of cement were tested. The dimension of the cement plug in the dovetail grooves was $6 \times 6 \text{ mm}$ and the distance between the grooves

was 26.5 mm . Further samples of 70 mm by 70 mm were tested by moulding them over the ends of the top of the U-bar. A thermocouple was put in the cement at a depth of 2 mm . The error was calibrated with a transducer and simultaneous readings for strain and temperature were recorded continuously on the graph.

The change in volume of the cement polymer was measured by a dilatometer.

The dilatometer was a standard dilatometer with a tight stopper and the change in volume was measured in a burette mounted in the center by recording the rise and fall of the column of water every 20 seconds. The measurements were started as soon as it was possible to handle the cement, i.e. 2 to 3 minutes after mixing the components. The volumes of the portions of cement used were measured by calculating displacement in water by weighing.

Three brands of acrylic cements were used: CMW Bone Cement¹, Surgical Simplex² and Palacos R³. Eight portions of the same production batch of each brand of cement were used to stress formation.

RESULTS

Temperature. All cements showed a sharp rise in temperature at a certain and for each brand a fairly constant time after the beginning of mixing the powder and the liquid. The average maximum temperatures reached were between 76° and 94°C . It should be noted that all cements just 2 mm below the surface reached temperatures that were well above the coagulation temperature for polymers. This occurred in both 8 mm and 4 mm specimens. CMW showed the highest average temperature and the highest average shrinkage. The cements where the temperature peaked later also showed slightly lower maximum temperatures. Mean maximum temperatures are given in Table I.

Table I Average values for force, shrinkage, maximum polymerization temperature and for shrinkage

Cement	Force N/mm	Shrinkage per cent	Average max temp $^{\circ}\text{C}$	Shrinkage mm
CMW	2.8 ± 0.03	1.0	94.0	0.11
Simplex	2.7 ± 0.06	2.0	76.0	0.1
Palacos	1.7 ± 0.05	2.0	84.0	0.09

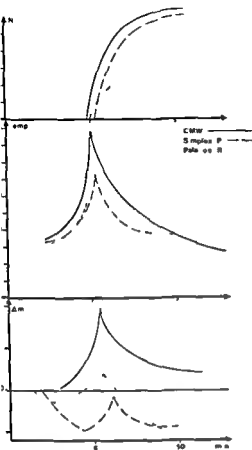


Figure 2 The time relationship between the development of force temperature changes and volume changes in acrylic cements

Volume The cements changed volume during polymerization the changes following consistent pattern in all experiments. The shape of the graphs for Simplex and Palacos were very similar and showed an initial contraction followed by an expansion again followed by a contraction. The graph for CMW was somewhat different as it did not show the "dip" but demonstrated a continuous expansion followed by contraction. Repeated experiments showed that the "dip" in the first part of the graph depends on the ambient temperature the "dip" being less pronounced at higher temperatures. The exact magnitude of the change in volume in the first soft phase of polymerization is difficult to assess as a true starting volume

cannot be obtained with the method used. For reasons given below these first changes of volume were found to be of no practical consequence and the matter was pursued no further. The graph in Figure 2 demonstrates the force of contraction and the changes in volume and temperature. When the volume curves are compared with the temperature and force recordings it will be noted that the time of maximum volume coincides within 15 to 30 seconds with the beginning of the formation of forces. The time elapsing from the beginning of mixing till the beginning of the final contraction of volume was between 6 and 10 minutes at 20°C and between 5 and 6 minutes at 38°C for all three cements. In Table 1 the percentage volume changes of the three cements are given. The final shrinkage involved in the build up of forces is between 2 and 3 per cent of the maximum volume recorded for each cement.

Stress The build-up of stress in the cement paralleled the decrease in temperature and reached maximum when the temperature curve had fallen and was levelling off. The average forces measured are shown in Table 1. The measurements showed that within the tested limits the build up of force is a linear function of the distance between anchoring points. The cross-sectional area had no influence on the values as these were the same for the 80 and the 160 mm² samples but they were proportionally larger for the samples 70 mm in length. Thus the build up of forces can be expressed per mm distance. The values for linear shrinkage are given in Table 1. The values for CMW and Simplex are of the same magnitude about 2.8 N/mm whereas Palacos demonstrated a lower value of 1.7 N/mm. Statistical analysis showed this difference to be significant ($P < 0.01$).

Calculation of forces and stress

The results of the present experiments may be used as a basis for a calculation of the forces that the polymerizing cement imposes on the acetabulum. The experiments

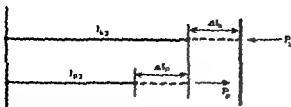


Figure 3 The relationship between two interacting elastic materials

demonstrate that the force per mm for the two distances of fixation of the cement, i.e. 26.5 and 33 mm, is the same, about 2.8 N/mm for CMW. This shows that the contraction of the cement that takes place is independent of the forces arising within the limits of the dimensions to be considered. However, when polymerization has taken place the two materials involved, the acetabular bone and the cement, may be considered as two elastic materials - springs - interacting with equal force on each other when forces and deformations of the two materials have reached an equilibrium. The forces may then be calculated from a knowledge of the data for the apparatus, the values found, and the known or estimated mechanical characteristics of the materials. In the following a simplified situation of uniaxial stress will be considered with the two materials acting as two springs in equilibrium (see Figure 3)

P_k = force acting on bone

P_p = force acting on cement

Δl = linear shrinkage of cement during unrestrained polymerization

l_k = distance between unloaded anchoring points

l_p = length of cement before polymerization

K_k and K_p = coefficients of stiffness of bone and cement

During the polymerization process the cement and the bone must assume the same length

$l_k = l_p$ = distance between anchoring points after polymerization.

Δl_k and Δl_p are considered elastic deformations

$P_k = P_p$ = the force acting on cement and bone due to polymerization
We will then have

$$(1) \Delta l = \Delta l_k + \Delta l_p \quad \Delta l_p = \Delta l - \Delta l_k$$

$$(2) P_k = \Delta l_k \times K_k$$

$$P_p = \Delta l_p \times K_p$$

$$(3) P_k = P_p$$

$$(2) \text{ and } (3) \quad \Delta l_k \times K_k = \Delta l_p \times K_p \quad \text{which gives}$$

$$(4) \Delta l_k = \frac{\Delta l_p \times K_p}{K_k}$$

This used in (1) will give

$$\Delta l_k = \frac{(\Delta l - \Delta l_k) K_p}{K_k}$$

$$\Delta l_k = \Delta l \times \frac{K_p}{K_p + K_k}$$

this applied to (2) gives

$$(5) P_k = \Delta l \times \frac{K_p \times K_k}{K_p + K_k}$$

If Δl and the coefficients of stiffness for bone and cement are known this equation will give the resulting force. In the present work the modulus of elasticity is used for the calculation of K . The coefficient of strain will be

$$K = \frac{P}{\Delta l} = \frac{\sigma \times A}{\Delta l} = \frac{E \times \epsilon \times A}{\Delta l} \quad \epsilon = \frac{\Delta l}{l}$$

K = coefficient of stiffness

P = force

E = modulus of elasticity

σ = stress

A = cross-sectional area

$$\epsilon = \text{strain} = \frac{\Delta l}{l} \quad \Delta l = \epsilon \times l$$

Example

CMW is used as an example using two holes of 6 mm diameter and distance of the cement of 4 x 20 mm.

The stiffness of the U bar apparatus K_f determined from the calibration

$$K_f = 554 \text{ N/mm}$$

$$\Delta l = \Delta l \times \frac{K_p \times K_f}{K_p + K_f} \quad \text{which gives}$$

$$\Delta l = P_f \times \frac{K_p + K_f}{K_p \times K_f}$$

$$\Delta l = \frac{E \times A}{l}$$

$$P_f = 260 \text{ kp/mm}^2 = 2550 \text{ N/mm}^2 \text{ (Holm 1977)}$$

$$l = 20 \times 4 \text{ mm} = 80 \text{ mm}$$

$$K_p = 7700 \text{ N/mm}$$

P_f is determined from K_f and the contraction measured (Table I)

$$P_f = \Delta l \times K_f = 0.13 \times 554 = 72 \text{ N}$$

Δl (the unstressed length of the cement) can now be determined

$$\Delta l = \frac{7.2(554 + 7700)}{554 \times 7700} = 0.14 \text{ mm}$$

This figure is used in the further calculations where P_k is the figure wanted (Equation (5))

For bone is a difficult figure to determine. The literature gives very varying values. Currey (1970) in his comprehensive article gives the findings of 13 investigators working on femoral cortical bone and quotes values from 49 000 to 214 000 kp/cm^2 , most values being of the order of magnitude of 150 000 kp/cm^2 . Dietschi (1976) found values of 80 000 kp/cm^2 - 785 kN in pelvic cortical bone and this value will be used here. The thickness of the cortical bone of the acetabular joint surface is from 2 to 4 mm. Thus

$$K_k = \frac{E \times A}{l} = \frac{785 \times 10^3 \times (6 \times 4)}{26.5} = 7112 \text{ N/mm}$$

By inserting in (5) P_k will be

$$P_k = \frac{0.14 \times 7700 \times 7112}{7700 + 7112} = 518 \text{ N}$$

This will be the resultant force on the bone in our uniaxial example. The stress on the bone will be

$$\sigma = \frac{518}{24} = 22 \text{ N/mm}^2$$

DISCUSSION

Temperature The temperatures found in this investigation are measured 3 mm below the surface of the cement polymerizing under water at body temperature. The values found here do not differ from those found by other investigators (Ohnsorge & Krosen 1969, Ohnsorge & Gobel 1969, Charnley 1970, Debrunner et al 1976). The exothermic nature of the polymerization process is a well established fact and will not be further dealt with here. The temperature changes are only taken as an indicator of the progress of the process. The fact that the temperatures rise to about 90° C even though the cement is surrounded on one side by metal and on the remaining surfaces by water demonstrates that the heat problem cannot be overcome by cooling.

Volume Debrunner et al (1976) found that the changes in volume were dependent on mixing techniques, ambient temperature, and speed of polymerization. He also demonstrated that the porosity is dependent on external pressure. Thus volume changes in the early phases of polymerization could be quite variable. The present experiment demonstrated slight differences between the cements in the relation between the contraction caused by the chemical process and the expansion caused by the heat generated by the same process. However these changes in volume that take place in the early phases of polymerization when the cement is still

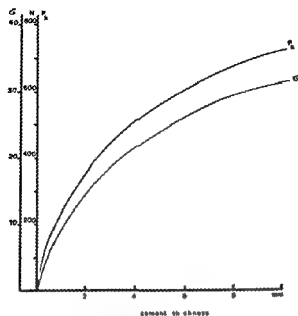


Figure 4 The variation in force, P_h , and stress, σ , with varying cement thickness

doughy are of no consequence as regards surgical use, as even a slight stress will merely cause the cement to flow. During this phase Charnley (1970) found no stress from expansion and in the present work the absence of forces from contraction is demonstrated. In this context the injection pressure of the cement will be the determining factor in the cement's "grip" on the bone. Thus only the final contraction when the cement has reached sufficient stiffness to support stress is of practical importance. The cause of the final contraction of the cement is a combination of thermal contraction from cooling and the final stage of polymerization. By calculating the expected change of volume from the coefficient of thermal expansion for acrylics it will be seen that the cooling is responsible for 40–50 per cent of the final contraction (Coefficient of thermal expansion $= 227 \times 10^{-6}$, Debrunner et al 1976). The present findings correspond well with the findings of Debrunner et al (1976). For the above-mentioned reasons it would not seem advisable to attempt to include large amounts of air in the cement by stirring in order to make the cement expand in the soft phase. More air increases the porosity of the cement

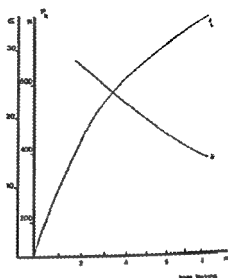


Figure 5 The variation in force P_h and stress, σ , with varying bone thickness

and therefore decreases its median strength.

Stress The present experiment was drawn as an investigation of the stress produced in the acetabulum when a cemented prosthesis is inserted. It seems obvious that the shrinkage of polymerizing and curing methylmethacrylate – when restricted in some way as in the usage in h.p. replacement – will generate stress. Charnley (1970) found no such stress, but the experimental device that he used was aimed at finding forces from expansion, not the stress arising from the final contraction. The values of final shrinkage found in the present experiment correspond well with the figures given by Willert & Semlitsch (1976) and are about 0.3–0.4 per cent. The development of force and stress in the acetabulum after insertion of the prosthesis will depend on the position of the prosthesis, but also on the thickness of the acetabulum, the distance between cement and bone, the distance between anchoring points, the size of the holes drilled and the E-moduli of the bone and the cement. The cement will have a very poor grip on a smooth sclerotic surface of the bone, but on the other hand irregularities, e.g. bone overhangs, will help distribute the force at the anchoring points of purchase for the cement. The

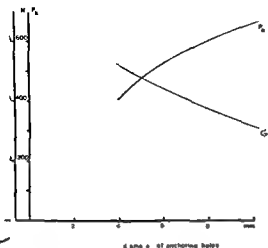


Figure 6 The variation of force, P_h , and stress, σ , with varying diameter of anchoring holes

influence of changes in the various parameters will be considered briefly, as an illustration, in each case keeping the other parameters constant. The force and the stress on the bone both increase as the thickness of cement increases. The relationship is shown in Figure 4. Differences in thickness of bone will alter the value of K_b . This influence is demonstrated in Figure 5. The force will increase as the bone gets stiffer, but as this is accomplished by increasing the thickness and thus cross-sectional area, the stress which is force per mm^2 will decrease. The same effect will be seen if the diameter of the anchoring holes is increased (with constant thickness of bone). This is shown in Figure 6. Changes in the distance between anchoring holes will only have a minor influence on the forces as will be seen from the calculations. If the distance is increased from 26.5 mm to 40 mm the force will only increase by about 4 per cent. The factor Δl increases from 0.14 to 0.15.

In surgery a three point fixation of the acetabular prosthesis is intended through the placement of three (or more) holes in the bone. The magnitude may be attempted. A calculation

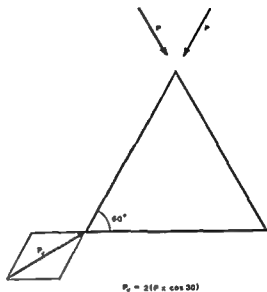


Figure 7 The calculation of force in a three-point fixation

of vectors will indicate an increase in the forces. If we make the simplified assumption of having the three points of fixation placed in the corners of an equilateral triangle we will have forces expressed by

$$P_h = 2(P \times \cos 30) = 1.73 P$$

(Figure 7). For the values found here this would mean that local forces of the order of magnitude of 500 to 1100 N would be acting at each of the points of fixation.

The calculations presented here are of course based on certain simplifications. The acetabulum is not a frictionless plane and both cement and bone form a continuous surface and not strips of 20 mm width. However the approximations were felt acceptable under the circumstances. The uncertainties and variations of the E-modulus for bone, which varies greatly — as between the thin, soft bone of a girl with rheumatoid arthritis and the sclerotic bone of a man with osteoarthritis — and the variation in the thickness of cement as well as the other factors involved will influence the forces greatly. Especially the E-modulus is important as it is such an important factor in the value of the bone constant K_b .

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THE RELAXATION OF SOME ACRYLIC BONE CEMENTS

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The creep and relaxation of acrylic cements during conditions simulating the conditions in the acetabulum have been examined CMW and Simplex were found to reach stresses of about 10 N/cm² after 1 year whereas Palacos had lost most of its stress after 6 weeks.

Key words bone cement, hip joint prosthesis

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The problems of loosening of acetabular components in total hip replacement are gaining importance. The details of how the acrylic cements transfer forces from the acetabular component of a total hip replacement to the bone are not well understood, but in a previous article (Holm 1980) the author has shown that acrylic cements may generate total stresses between the anchoring holes drilled into the acetabular bone of up to about 1000 N, mainly because of contraction when cooling. It is well known that plastics will creep and undergo relaxation under load, i.e. plastic deformation occurs with time. The present investigation is an attempt to evaluate the speed of creep and relaxation of some acrylic cements.

MATERIAL AND METHODS

Three brands of cement were tested, CMW Bone Cement[®], Surgical Simplex[®], and Palacos R[®]. The apparatus and experimental setup has been described in detail in a previous paper (Holm 1980). It consisted of a measuring device in which the linear contraction of methylmethacrylate was evaluated by measuring the deformation of a U-shaped spring. The acrylic specimen was moulded across the open end of the "U" and allowed to contract. The relaxation was then measured under

a slowly decreasing load as the U-spring regained its original shape. The test pieces for the present experiment were all 20 × 8 mm and the distance between anchoring points was 26.5 mm. The cement was mixed at room temperature (22°C) by hand according to the manufacturers' instructions and placed in the mould to obtain the correct dimensions. The initial deformation, i.e. linear shrinkage, was measured with a dial gauge from which further daily readings were taken. Two samples of CMW were tested as well as two of Simplex and one of Palacos R. One long term experiment was conducted with CMW. The individual experiments were continued for about 3 weeks whereas the long term experiment lasted 3 months. All experiments were carried out in distilled water at 38°C.

The standard method of testing creep involves loading the test piece in tension with a constant stress and expressing the elongation as a function of time. A relaxation test is made by straining a given test piece to a given length in tension or compression and measuring the stress as it falls towards zero. In the present experiment the relaxation of the cement is evaluated by a test with very small values of strain and a slowly decreasing value of stress. It is thus a compromise between a creep and a relaxation test. This method was chosen in order to get an estimate of the time factor involved when the cement is anchored to the bone where the stress will decrease as the cement creeps.

The creep of a plastic material can be expressed by the formula

$$\epsilon = \epsilon_0 + m t^n \quad (\text{Schreyer 1972}) \quad (1)$$

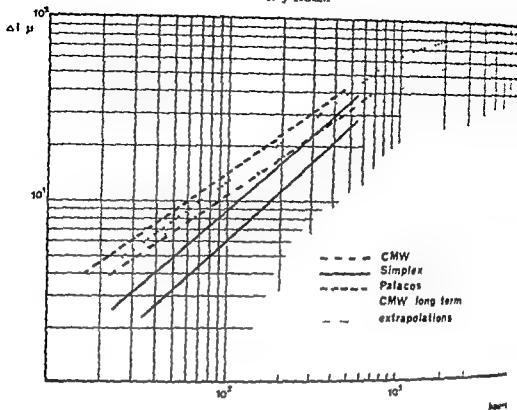


Figure 1 Creep of some acrylic cements Double logarithmic presentation with extrapolations

ϵ = strain at a given time ϵ_0 = strain at the time = 0 ϵ_0 thus is the strain which occurs immediately upon loading, i.e. basically the elastic strain m and n are material constants. m is a temperature dependent constant and on the graph it will be the projection to the time = 1 n is the inclination of the line and is independent of the stress. The equation $\epsilon = \epsilon_0 + mt^n$ can be transformed to $\ln(\epsilon - \epsilon_0) = \ln m + n \times \ln t$ and in logarithmic form we have

$$\ln(\epsilon - \epsilon_0) = \ln m + n \times \ln t \quad (2)$$

which is a useful expression for a double-logarithmic presentation

In the present experiment the elongation, Δl was measured directly and was used instead of the strain

ϵ_0 was difficult to determine with accuracy as the test piece had been under stress for some time before the first reading could be taken. In other words, an exact starting time could not be determined because of the continuous nature of the polymerization process. Furthermore ϵ_0 is based on the condition of constant stress whereas the stress in the present experiment, as in the acetabulum, was decreasing with time. In the calculation, therefore, Δl is substituted for $\epsilon - \epsilon_0$, as $\epsilon \sim \epsilon_0 \times 26.5 \text{ mm} = \Delta l$.

Thus means that the values obtained for ϵ_0 are only valid for a distance between sections of 26.5 mm and are therefore of minor importance whereas the n -value which is independent of ϵ_0 is the important figure

RESULTS

The results are shown graphically in Figure 1. Figure 2 shows the percentage relaxation in the five experiments. The values of n were calculated by linear regression and given in Table I together with the coefficient of correlation, the maximum linear shrink, the percentage relaxation, and the shrink at 500 hours, $\Delta l_{500} - \Delta l_{\text{max}}$. Special consideration will be given to the correct values in the long term experiments.

The first observation to be made in the mathematical expression is valid as shown the coefficients of correlation are large. The formula is designed to describe a regular

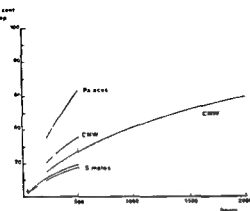


Figure 2 Percentage creep of some acrylic cements

ST This holds true up to about 500 hours. The primary linear shrinkages were not different from those previously reported (Holm 1980), i.e. approximately the same values were obtained for CMW and Simplex and a considerably lower value for Palacos. Also Palacos showed an m -value which was about twice the value for the two other brands. These two factors, a high m -value and a low linear shrinkage, account for the rapid relaxation of Palacos of 68 per cent in 500 hours as compared with 20 per cent for Simplex and 30 per cent for CMW. The n -values which represent the inclination of the lines in Figure 1 do not vary greatly and are between 0.7 and 0.8. The lines are therefore almost parallel. The long-term experiment with CMW shows that the cement no longer follows the mathematical expression after about 500–550 hours. As will be seen from the graph the curve levels off indicating that

the relaxation proceeds much more slowly as the stress decreases. A new n -value has been calculated which demonstrates the extension in time. This n -value will only be valid up to about 2000 hours. After this time the n -value decreases further, but at that time the experiment was discontinued. At 2000 hours about two-thirds of the shrinkage had relaxed and the stress in the test sample at this time could be calculated to be

$$\frac{0.058 \text{ mm} \times 554 \text{ N}}{1.6 \text{ cm}^2} = 20 \text{ N/cm}^2$$

The m -value for this section of the test is a theoretical extrapolation and is of no interest.

DISCUSSION

As shown in a previous paper (Holm 1980) methylmethacrylate, when used in fixation of acetabular components with anchoring holes, creates considerable forces which contribute to the fixation of the cup. As plastics are known to creep it is important to know the length of time the forces are present. The relaxation and creep of acrylics have been fairly well investigated (Schreyer 1972). A number of factors make the evaluation of acrylic cements complicated. Commercial acrylics such as Plexiglas[®] show a creep of about 1 per cent per year under standard conditions.

Several factors will, however, increase this factor. The temperature has a definite influence, creep increases when the temperature increases. Another factor which

Table 1 Calculated values for n and m , coefficient of correlation, maximum linear shrinkage, shrinkage at 500 h and the percentage creep/relaxation at 500 h

	n	m	Coefficient of correlation	Δl_{max} mm	$\Delta l_{\text{max}} - \Delta l_{500}$ mm	Per cent relaxation at 500 h
CMW 1	0.7	0.4	0.98	0.094	0.062	34
CMW 2, 500 h	0.8	0.3	0.99	0.145	0.104	29
CMW long-term at 500 h	0.5	(2.1)	0.99	0	0.058 (2000 h)	60 (2000 h)
Simplex 1	0.8	0.1	0.98	0.132	0.106	19
Simplex 2	0.8	0.3	0.98	0.134	0.108	19
Palacos P	0.7	0.7	0.99	0.068	0.025	62

greatly increases the speed of creep is humidity.

Creep and relaxation are simply two ways of describing the same phenomenon. The mechanism which is at work consists of a stretching and realignment of molecules which is greatly facilitated by the presence of water which acts as an internal "lubricant". As shown by Ohnsorge & Grötz (1974) acrylic cement will absorb 1.3 per cent by volume of water, which accounts for a part of the creep. To these variables are added the degree of polymerization of the cement, i.e. the length and branching of the molecules, and the amount of air incorporated in the cement during mixing.

The present results comply well with the general knowledge of relaxation and creep (Schreyer 1972). At the termination of the experiments there was still considerable stress in the CMW and Simplex samples whereas Palacos had lost most of its stress. The results may be extrapolated forwards in time but the estimates will contain considerable uncertainty. It seems reasonable to assume that all acrylic cements behave in a similar manner and it will be seen from Figure 1 that the curves are asymptotic. An estimate of the time when the stress has reached 10 N/cm^2 ($\approx 0.03 \text{ mm}$ shrinkage) can be made from the graph. This will show that the time for CMW will be of the order of magnitude of $1-2 \times 10^4$ hours $\approx 1-2$ years. The time for Simplex is difficult to evaluate, but it will not be shorter rather the opposite as it shows only 20 per cent relaxation at 500 hours. For Palacos, the time will be considerably shorter, the graph would indicate less than 1000 hours.

The physical behaviour of acrylic bone cement has clinical significance in terms of mechanical fixation and loosening. Immediately following polymerization the cement has a grip on the bone of 500-1000 N (CMW, Simplex). This force counteracts the forces of friction. As it decreases with time friction prevails and mechanical loosening may start.

The behaviour of bone in terms of relaxation and creep is difficult to evaluate. In fact,

when loaded in compression creep is not to be expected when the composition of a composite biological material is constant. The compression forces will be sustained by the apatite crystals in the bone and the substance cannot be expected to undergo creep. If a plastic deformation were to occur it would come from remodelling as long as loads are within the tolerances of the bone. Hert et al. (1969) have shown that a strain on bone causes no discernible remodelling. Perren et al. (1969) measured the stress in the compression plates used in the femoral osteotomies and found decreasing stress with time, but their results are not directly applicable in the present context as they were measuring the strain with an extensometer between the measuring points. Such a situation does not exist in the acetabulum where the anchoring holes are placed through otherwise basically intact cortical bone.

It is evident that any remodelling or resorption of bone at the edges of the anchoring holes in the acetabulum will rapidly decrease the cement forces. In cases where the cement for some reason fails to be set in cancellous bone no stress is transferred and therefore no relaxation can be expected.

CONCLUSION

The acetabular component of a total hip replacement when fixed by means of anchoring holes for the cement in the acetabular corticalis is held in place by the contraction forces of the cement for a certain period of time. The speed with which the acrylic compound undergoes relaxation is dependent on the type of cement used, it creeping much faster than CMW and Simplex - and on the response of the bone.

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TENSILE FRACTURE OF CANCELLOUS BONE*†

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Excised specimens of cancellous bone from human femora were subjected to compressive or tensile testing, and the resulting force-displacement curves were recorded. The relationships between bone strength and apparent density were similar for specimens tested in these two loading modes. The modulus of elasticity was also comparable for the tensile and compressive specimens. Specimens loaded in compression absorbed considerable energy after the initial fracture because of progressive impaction of the trabeculae. In the specimens loaded in tension, the fractured bone fragments separated and therefore absorbed little additional energy after the initial failure. The energy absorption capacity was thus significantly lower for the tensile specimens.

The results of this study show that the primary difference in mechanical properties of cancellous bone tested in tension and compression is the energy absorption capacity. This finding suggests that tensile and avulsion fractures of cancellous bone observed clinically are associated with minimal energy absorption and therefore may be precipitated by relatively minor trauma.

Key words: apparent density, cancellous bone, elastic modulus, energy absorption, strength

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Cancellous bone plays an important role in the transmission and distribution of stresses in the human skeletal system, particularly in the vertebral column, in synovial joints, and in ligamentous and tendinous attachments. Previous mechanical testing of cancellous bone specimens *in vitro* has been conducted primarily in compression (Carter & Hayes 1977, Galante et al. 1970, Lindahl 1976, McElhaney et al. 1970, Townsend et al. 1975b). Data from some of these studies indicate that cancellous bone acts very much

like porous engineering materials which have many applications because of their excellent energy absorption capabilities (Hayes & Carter 1976, Patel 1969, Pramuk 1976). The stress-strain curve for a rigid cellular plastic tested in compression is very similar to that for cancellous bone (Figure 1). Compression curves for both materials consist of an initial linear region followed by yield and a long "plateau" region where the stress remains approximately constant as the strain is increased. In the plateau region the cellular plastic or cancellous bone is being gradually compressed and the small struts of material (trabeculae in cancellous bone) are fracturing. At very high strain values, debris begins to fill the pores of the material, and the specimen stiffness increases markedly. The

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vacuum. The specimens were then suspended from an analytical balance to determine the submerged weight. They were centrifuged on blotting paper for 15 minutes to remove residual water from the pores and weighed in air to obtain dried tissue weight. The volume of bone tissue (cubic centimetres (excluding pores)) was calculated as the difference between the hydrated tissue weight and the submerged weight expressed in grams (Mueller et al 1966). Tissue density of the specimen was calculated by dividing hydrated tissue weight by bone tissue volume. Apparent density of the specimen was calculated by dividing hydrated tissue weight by bulk volume of the specimen as determined by micrometer measurements. Bone porosity, defined as the percentage of bone volume occupied by non-mineralized tissue, was calculated as

$$P = 100 \left(1 - \frac{\rho}{\rho_t} \right)$$

where P = porosity (per cent)

ρ = apparent density

ρ_t = tissue density

After measurements were made, the specimens were allowed to dry overnight in room air.

The configuration used for testing was a modification of ASTM standard D 1623 for tensile testing of rigid cellular plastics (ASTM, 1978). The ends of the dried specimens were embedded to a depth of approximately 1.65 millimetres with a polyester embedding resin. After the resin had cured the ends of the specimen were bonded with a polyamine blend of diglycidyl ester bisphenol (Devcon) in small metal platens which could be held conveniently in the grips used for mechanical testing (Figure 2).

Before testing, the specimens were rehydrated with saline solution and maintained in a wet condition during the testing procedure. Tensile and compressive loading to failure was done at 21 degrees centigrade with an MTS loading system at a constant strain rate of 0.01 per second. A force-displacement curve was recorded for each specimen tested. This curve was later used for data analysis. Twenty-eight specimens with marrow extracted were tested in tension and sixteen were tested in compression. To evaluate the influence of the specimen preparation procedures on the mechanical properties, we tested an additional 10 specimens (5 in tension and 5 in compression) from which the marrow had been extracted with a jet of warm water.

Initial attempts to bond the wet specimens to the small metal platens resulted in an unsatisfactory bond. It was therefore necessary to dry the specimens before bonding them and rewet these specimens prior to testing. This procedure was a

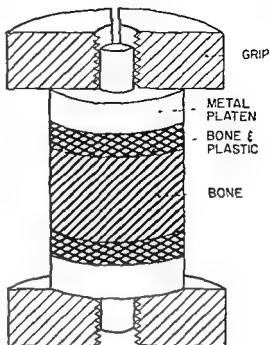


Figure 2 Specimen testing configuration

source of concern, as other researchers have shown that drying of bone tissue can cause

had been removed with a jet of warm water, had not been bonded to the metal platens and had not been allowed to dry at any time

RESULTS

The tissue density of the bone specimens examined was between 1.6 and 1.95 grams per cubic centimetre. These values are comparable to those commonly found in human cortical bone (Gong et al 1964). The values for apparent density of the specimens ranged from 0.2 to 0.8 grams per cubic centimetre. The specimen porosity ranged from approximately 50 to 90 per cent.

The force-displacement curves recorded for the specimens tested in compression were similar to those reported in earlier compression studies of cancellous bone (Figure 1B).

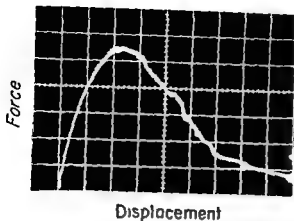


Figure 3 The force versus displacement curve of a specimen tested in tensile loading

The force-displacement curves recorded for the specimens tested in tension, however, differed markedly from those for the compression specimens. These tensile curves were characterized by an initial linear region followed by a region which was nonlinear until the maximum force was achieved. Beyond this point progressive trabecular fracture occurred, resulting in a gradual loss of force with increasing displacement until total separation of the fracture surfaces was observed (Figure 3). The gradual decrease in force after the maximum force was achieved was accompanied by a tearing phenomenon wherein the trabeculae of the cancellous bone progressively tore free from the adjacent bone.

The area under the force-displacement curve for the specimens represents the energy absorbed. Under small strain conditions the energy absorption capacity of the specimens was virtually identical in tension and compression. Under large strain conditions (fracture), however, the tensile specimens absorbed very little energy, since after fracture occurred the bone ends separated and no further forces were transmitted through the specimens. Compressive fracture of the specimens led to progressive impaction of the trabeculae and prolonged energy absorption.

The strength of the specimen was defined as the maximum stress achieved before progressive trabecular tearing (in the case of

tension) or collapse (in the case of compression). The elastic modulus of the specimen was calculated using a mathematical model which accounted for altered compliance at the embedded ends of the specimens (see Appendix).

There had been some concern that the specimens might fracture at the interface between the bone and the embedding material. However, the compression specimens experienced diffuse fracture of the trabeculae throughout the specimen, and the tension specimens fractured through the cancellous bone rather than at the plastic interface. This fracture behavior suggests that the interface did not serve as a site of stress concentration.

All specimens which were dried and rewetted for testing showed comparable material properties whether the marrow was extracted by chemical means or by washing. However, the compression specimens which were kept wet throughout the preparation procedure were generally more compliant than specimens which were dried and rewetted. Data for these fresh specimens are presented separately.

The apparent density had a significant influence on the ultimate strength of both compression and tension specimens (Figure 4). Since a power relationship between ultimate strength and apparent density was anticipated (Carter & Hayes 1977), the data are presented on a log-log graph. Analysis of covariance revealed no statistically significant difference in the ultimate strength of the dried and rewetted specimens tested in the two loading modes, although significant dispersion was present. The compression specimens which were tested fresh, however, showed a slightly lower ultimate strength than specimens which had been dried and rewetted. The relationships between strength and apparent density for all specimens were consistent with those from earlier compression tests of fresh cancellous bone (Carter & Hayes 1977).

The apparent density also had a significant influence on the elastic modulus of the

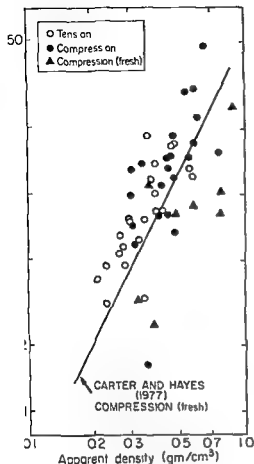


Figure 4 The influence of apparent density on the tensile and compressive strength of cancellous bone

specimens (Figure 5). Again, no statistically significant difference was found in the elastic moduli of dried and rewetted specimens and in the two loading modes. However, the elastic moduli for these specimens were significantly greater than those for the common specimens tested fresh. The elastic moduli of these fresh specimens were in agreement with those from the earlier compression tests of fresh cancellous bone (Carter & Hayes 1977). These findings suggest that although the elastic moduli for rewetted specimens were the same in tension and compression, the numerical values may be significantly greater than those for fresh specimens.

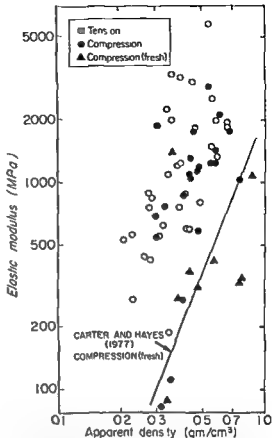


Figure 5 The influence of apparent density on the tensile and compressive elastic modulus of cancellous bone

DISCUSSION

In this study the strength of cancellous bone was found to be comparable in tensile and compressive loading. In both loading modes, the strength of the bone was approximately proportional to the square of the apparent density. This finding is consistent with that of a previous study on the influence of apparent density on the compressive behaviour of fresh cancellous bone specimens (Carter & Hayes 1977). The elastic moduli of the dried and rewetted specimens of this study were the same in tensile and compressive loading. The modulus values of the rewetted specimens, however, were

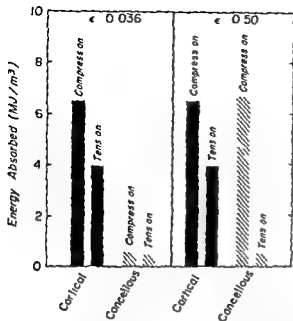


Figure 6 The energy absorption capacity of cortical and cancellous bone at low strains (strain = 0.036) and at high strains (strain = 0.50). The assumed apparent density of the cancellous bone is 0.4 grams per cubic centimetre. Energy absorption for cortical bone is derived from the study of Reilly & Burstein (1975).

significantly greater than those of fresh specimens tested in compression in this and a previous study (Carter & Hayes 1977). At small strains, the energy absorption capacity of the cancellous bone specimens was approximately the same in tension and compression. However, at large strains the specimens showed a much greater capacity to absorb energy in compression than in tension.

In *in vivo* situations, tensile fracture of cancellous bone causes displacement of the fractured bone ends, after which no further energy can be absorbed by the bone. In compressive fracture of cancellous bone, however, initial fracture is followed by progressive impaction of the trabeculae, which results in high energy absorption. Displacement of the fractured bone ends occurs in all fractures of cortical bone, preventing further energy absorption after initial fracture. At a strain of approximately 50 per cent (as may be encountered with severe trauma), the energy absorbed in fracture of cancellous bone in

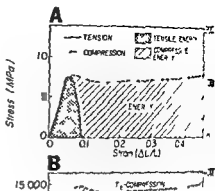


Figure 7 A The tensile and compressive stress-strain behaviour of cancellous bone with an apparent density of 0.4 grams per cubic centimetre. B The force-deformation curve for compression fracture of the twelfth thoracic vertebra and a tensile fracture of the patella.

compression can exceed that absorbed in fracture of cortical bone under any load condition (Figure 6).

The cancellous bone specimens in this study were taken from an 84-year-old subject. With increasing age there may be a general decrease in cancellous bone apparent density (Lundahl & Lindgren 1962). This decrease is caused primarily by an increase in bone porosity since the ash weight of bone remains constant or increases very slightly after the age of 20 years (Currey & Butler 1975, Badier et al 1974, and Carter & Spengler 1977). The mechanical properties in this study were evaluated as a function of bone apparent density. These relationships should therefore provide a sound basis for estimating the mechanical behaviour of cancellous bone for any age specimen, provided that the apparent density of the bone can be assessed.

Specimens of this study were tested at a strain rate of 0.01 per second. Carter & Hayes (1977) demonstrated that the strength and modulus of cancellous bone is approximately proportional to the strain rate raised to the 0.06 power. This finding suggests that



Figure 8 A Tensile fracture through cancellous bone of the patella with an energy absorption of approximately 3 joules B Compression fracture of a vertebral body with an energy absorption of approximately 100 joules C Torsional fracture of the tibia with an energy absorption of approximately 3 joules

during impact loading with a strain rate of 10 per second, the values for strength and modulus recorded in this study would be decreased by approximately 32 per cent. Differences in trabecular orientation between specimens could easily affect the mechanical properties by an equivalent or greater amount (Salante et al 1970).

The mechanical behaviour of cancellous bone described in this study and previous studies (Carter & Hayes 1977) can be related to the characteristics of fractures through specific cancellous bone structures. As an example, we estimated the fracture behaviour of the twelfth thoracic vertebra in compression and the patella in tension. Stress-strain curves were estimated for cancellous bone under compressive and tensile loading based on an apparent density consistent with the findings of this study and other studies (Carter & Hayes 1977, Kazarian & Graves 1977). From these stress-strain

curves, force-deformation curves were generated for tensile fracture of the patella and compressive fracture of the twelfth thoracic vertebra (Figure 7). Estimation of these force-displacement curves took into account the difference in geometry of the two structures. The curve estimated for the vertebra is consistent with experimental findings of Kazarian & Graves (1977).

The estimated force required to fracture the patella is less than that required to fracture the vertebral body simply because the patella is smaller. The estimated energy absorbed by the patella is markedly less than that absorbed by the vertebra not only because of its smaller size, but also because less energy is absorbed by cancellous bone in tension than in compression.

The amount of energy absorbed during a tensile fracture of the patella can be calculated from the force-deformation curve as approximately 3 joules (Figure 8A). In

contrast, the energy absorbed during a severe compression fracture (1 centimetre of deformation) of a vertebral body is approximately 100 joules (Kazarian & Graves 1977), and the energy absorbed by a torsional fracture of the tibia is approximately 10 joules (Burstein & Frankel 1968) (Figures 8B and C). This observation emphasizes that relatively minor trauma can produce avulsion fractures and tensile fractures through cancellous bone.

APPENDIX

Estimation of elastic modulus of cancellous bone from force-displacement data

The tested specimen consisted of cancellous bone with a cross-sectional area (A) and a length (L). The ends of the specimens were embedded in plastic resin to a depth of $0.5 L_{BP}$ so that the length of cancellous bone was L_B (Figure 9). Under a force (F), the total deformation recorded (ΔL) was caused by the deformation of the exposed cancellous bone (ΔL_B) and the deformation of the bone-plastic specimen ends (ΔL_{BP}).

$$\Delta L = \Delta L_B + \Delta L_{BP} \quad [1]$$

or

$$\Delta L = L_B \epsilon_B + L_{BP} \epsilon_{BP} \quad [2]$$

where ϵ_B and ϵ_{BP} are the strains in cancellous bone and bone-plastic composite respectively. Equation 2 can be re-written as

$$\epsilon_B = \frac{1}{L_B} (\Delta L - L_{BP} \epsilon_{BP})$$

The elastic modulus of cancellous bone (E_B) is equal to the stress (F/A) divided by the bone strain (ϵ_B). Expressing this in terms of Equation 3 yields

$$E_B = \frac{L_B(F/A)}{\Delta L - L_{BP} \epsilon_{BP}}$$

The strain experienced by the bone-plastic composite at the specimen ends (ϵ_{BP}) is

$$\epsilon_{BP} = \frac{F/A}{E_{BP}}$$

where E_{BP} is the elastic modulus of the bone-plastic composite. E_{BP} can be approximated by mixture theory as

$$E_{BP} = f E_p + (1-f) E_{CB}$$

or

$$E_{BP} = E_{CB} - f(E_{CB} - E_p)$$

where

f = void fraction of cancellous bone
 E_p = elastic modulus of solid plastic
 E_{CB} = elastic modulus of compact bone comprising the trabeculae

Substituting equation [7] into equation [2] yields

$$\epsilon_{BP} = \frac{F/A}{E_{CB} - f(E_{CB} - E_p)}$$

Substituting equation [8] into equation [2] yields

$$E_B = \frac{L_B(F/A)}{\Delta L - L_{BP} \left[\frac{F/A}{E_{CB} - f(E_{CB} - E_p)} \right]}$$

or

$$E_B = \frac{L_B}{\left[\frac{A}{(F/\Delta L)} - \frac{L_{BP}}{E_{CB} - f(E_{CB} - E_p)} \right]}$$

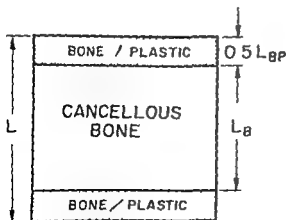


Figure 9 Schematic drawing of a tested specimen

- $L_B = 0.0067$ metres (estimated from ten specimens)
 $L_{BP} = 0.0033$ metres (estimated from ten specimens)
 $A = 0.0000785$ square metres
 $E_p = 3.5$ gigapascals (from manufacturer)
 $E_{CB} = 20$ gigapascals (estimated from literature)
 f = void fraction, calculated for each specimen
 $F/\Delta L$ = slope of the force-displacement curve, measured for each specimen

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EFFECT OF DIAPHYSEAL INJURY ON THE PROXIMAL GROWTH ZONE OF THE TIBIA IN RABBITS

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found that the disturbed circulation and the venous stasis may have a marked effect on osteogenesis and bone growth but other factors are probably also involved. In the early stage after the injury an increase in the ground substance, widening of the zone of generative and proliferative cells in the growth plate and a reticular arrangement of the bony trabeculae in the metaphysis were observed. In the late stage, along with a return to normal circulation, normalization of the osteogenesis and bone growth was also found.

Key words circulatory disturbance, diaphyseal injury, growth cartilage, metaphysis, radioactive isotopes

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It is well known that diaphyseal fracture or other trauma in childhood may enhance longitudinal bone growth (Bisgard 1936, Bunt 1955, Emneus & Hedström 1964, Saheli 1967, Edwardsen 1976). The exact mechanism of this enhancement is not yet known.

The aim of the present investigation was to study the epiphyseal and metaphyseal reaction following diaphyseal injury. Histological methods, radioactive isotopes and radiography were used in the experiments.

MATERIAL AND METHODS

A total of 130 four-week-old chinchilla rabbits with an average weight of 665 g were used for the experiments. The following diaphyseal injuries were inflicted under Nembutal anaesthesia, to the right tibiae of the rabbits:

Group 1 In 40 animals the anterior surface of the tibia was exposed, the periosteum longitudinally incised and then circularly detached in the middle third of the bone. Care was taken not to damage the nutritive artery and the perichondrium of the bone ends.

Group 2 In 40 animals after exposure of the middle third of the tibia and stripping of the periosteum, a hole was drilled into the medullary cavity on the anterior surface at the border of the middle and distal thirds of the bone using a dental drill. Care was taken not to damage the nutritive artery and the perichondrium of the bone ends.

Group 3 In 40 animals the tibia was fractured manually, without exposure, in the antero-posterior direction on the border of the middle and distal thirds of the bone, about 2 cm proximal to the distal end. The site of fracture was measured before actually breaking the bone and it was always distal to the foramen nutritium of the tibia. After reduction of the fracture a cast was applied and worn for 2 weeks.

Group 4 Ten animals received a cast similar to that used in group 3 and wore it for 2 weeks, however the cast was applied without prior injury.

From groups 1, 2, and 3 ten animals from each group were killed by intravenous air embolism 2, 6, 12 and 18 weeks after the bone injury. All the animals from group 4 were killed after 2 weeks. Both lower limbs were removed, the tibiae were cleaned and the left tibia was used as control.

The following examinations were performed:

(i) Bilateral X-ray pictures were taken of every pair of tibiae and qualitatively evaluated.

(ii) Seventy-two hours before killing 2 ml blood was taken from two animals from each group, 3.3 per cent sodium citrate and 30 $\mu\text{Ci Na}_2^{51}\text{CrO}_4$ (specific activity 369 Ci/g) was added to this blood and the mixture was incubated for 60 minutes at 37°C. Unbound ^{51}Cr was eliminated by three washings in 0.16 M NaCl. The ^{51}Cr labelled erythrocyte suspension was then diluted to its original volume with physiological NaCl solution and injected intravenously to the donor animal 48 hours before killing.

Five animals from each group received a 50 $\mu\text{Ci/kg}$ body weight $^{89}\text{SrCl}_2$ solution (specific activity 3.3 Ci/g) intravenously 48 hours before killing. After the animals were killed the proximal ends of the tibiae were halved in the frontal plane and under a magnifying glass an 8–10 mm high circular segment including the growth plate and the metaphysis, was removed in the horizontal plane. The radioactivity of the removed samples was measured in an FH-49, Friesche-Hoepfner well type scintillation counter. Radioactivity was expressed in cpm/g (counts per minute/gram sample weight) related to the unit weight of the control specimen.

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(iii) The proximal ends of the tibiae, after fixation in 4 per cent neutral Formalin decalcification in EDTA and embedding in paraffin were cut in the frontal plane into 7 μ thick sections and stained with haematoxylin-eosin.

The height of the columns of growth cartilage cells was measured as follows: an ocular micrometer with a scale divided into 100 equal parts of 10 μm each was inserted and a 41 projective and a 10/0.25 objective light microscope was used. One unit of the micrometer corresponded to 10 μm . On each slide measurements were made at three sites, in the middle and on the two marginal areas of the growth cartilage and in 5 views. The height was defined in micra as

$\text{Na}_2^{51}\text{CrO}_4$ and $^{89}\text{SrCl}_2$ was supplied by the Central Institute of Physical Research Budapest.



Figure 1a and b Comparative anteroposterior and lateral (b) roentgenograms of the fractured and control tibiae 2 weeks after the fracture. Increased transparency in the area of the fractured bone.

arithmetic mean of the values measured. The values were analysed statistically, according to the method of Snedecor (1962). The standard deviation and the standard error were calculated. The significance levels were used in the test of significance: highly significant $P < 0.01$, significant $P < 0.05$.

RESULTS

A Early stage (2-6 weeks) after all three types of diaphyseal injury

Roentgenograms revealed normal growth plate bilaterally. Under the growth plate a narrow sclerotic zone could be observed in the majority of the cases, generally on both sides. In the injured bones an increased opacity was found in the metaphysis. This phenomenon was most noticeable after diaphyseal fracture (Figure 1a and b). The concentration of ^{51}Cr labelled erythrocytes was markedly greater in the injured bone, especially after diaphyseal fracture (Table 1). The measured radioactivity of ^{85}Sr was also significantly greater in the injured bone. The difference was most marked after diaphyseal fracture (Table 2a and b).

At the site of the injury, proliferation of the mesenchymal cells and thick fibrous tissue was found. Fibrous callus could be observed in the vicinity of the drill hole and the fracture. In the metaphysis of the injured

bone enlarged sinusoids filled with erythrocytes and an eosinophilic homogenous substance were found. The bone marrow showed signs of stasis (Figure 2a and b). In the growth cartilage the ground substance was increased, the zone of the germinative and proliferative cells widened and the cell columns were irregular (Figure 3a and b). The trabeculae of the metaphysis in the primary spongiosa were thick, consisted of immature bony tissue and had a reticular appearance (Figure 4a and b). The growth cartilage of the injured bone was significantly higher than that of the intact bone (Figure 3a and b).

Roentgenograms and qualitative histological examination did not show any difference between the uninjured immobilized and control extremities after 2 weeks. The concentration of ^{51}Cr labelled erythrocytes was increased though not significantly on the immobilized side (Table 1). The increase in ^{85}Sr activity on this side was not significant and the growth plate was also not significantly higher (Table 2a and b, Table 3a and b).

B Late stage (12-18 weeks) after all the three types of diaphyseal injuries

Roentgenograms revealed no difference between the bone structure of the injured and uninjured proximal ends of the tibiae. Due to

Table 1 The increase in radioactivity of the proximal end of the tibiae, on the injured and immobilized side, after the injection of ^{51}Cr labelled erythrocytes, expressed as a percentage of control

	2 weeks	6 weeks	12 weeks	18 weeks
Periosteal stripping	55.0 52.0	15.4 12.4	8.7 7.1	7.0 4.8
Cortical drilling	89.7 89.2	26.0 25.9	9.1 6.8	6.4 5.3
Fracture	94.8 91.8	40.9 39.7	14.7 13.7	5.1 3.9
Cast only	7.1 6.9			

Number of animals in each group: 2

Table 2a ^{85}Sr activity measured in the proximal end of the right and left tibiae, expressed as counts per minute/gram

	2 weeks		6 weeks		12 weeks		18 weeks	
	right side M \pm SE	left side M \pm SE	right side M \pm SE	left side M \pm SE	right side M \pm SE	left side M \pm SE	right side M \pm SE	left side M \pm SE
Periosteal stripping	13794 \pm 961	9505 \pm 665	11495 \pm 924	9287 \pm 766	8611 \pm 694	8009 \pm 583	11063 \pm 516	10867 \pm 402
Cortical drilling	20165 \pm 843	12039 \pm 754	32250 \pm 729	28006 \pm 598	24765 \pm 1133	23778 \pm 812	4072 \pm 113	3991 \pm 108
Fracture	27064 \pm 704	15388 \pm 434	16494 \pm 816	11211 \pm 571	14720 \pm 1596	13064 \pm 1436	25190 \pm 711	24790 \pm 561
Cast only	24815 \pm 1140	23840 \pm 815						

Number of animals in each group 5

M = mean

SE = standard error

Table 2b The rise in ^{85}Sr activity in the proximal end of the tibiae, in the injured and immobilized side, expressed as a percentage of the control

	2 weeks	6 weeks	12 weeks	18 weeks
	M \pm SE	M \pm SE	M \pm SE	M \pm SE
Periosteal stripping	45.1 \pm 0.5	24.0 \pm 1.1	87 \pm 18	18 \pm 0.9
Cortical drilling	64.3 \pm 1.3	29.4 \pm 1.3	50 \pm 1.3	23 \pm 1.0
Fracture	76.0 \pm 2.0	47.2 \pm 1.1	113 \pm 0.7	18 \pm 1.1
Cast only				

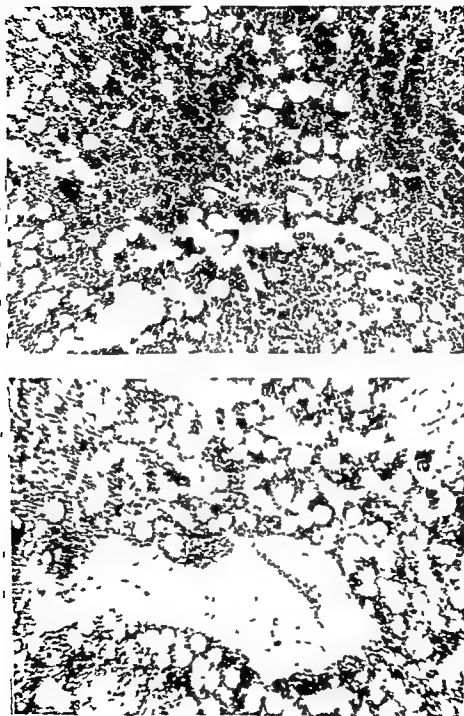


Figure 2a The dilated sinusoids of the metaphyseal bone marrow are full of erythrocytes. Signs of stasis are seen. Haematoxylin eosin $\times 40$. b Metaphyseal bone marrow of the intact tibia. Haematoxylin eosin $\times 40$.

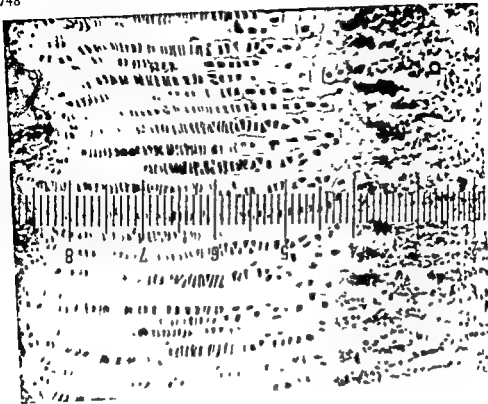


Figure 2a. The growth cartilage of the injured bone is covered by osteoblasts. The growth cartilage of the intact rib is covered by osteoblasts. (H&E, 10x)

	2 weeks		6 weeks		12 weeks		18 weeks	
	right side M ± SE	left side M ± SE	right side M ± SE	left side M ± SE	right side M ± SE	left side M ± SE	right side M ± SE	left side M ± SE
Periosteal stripping	658 ± 10	566 ± 8	545 ± 11	486 ± 9	443 ± 6	439 ± 9	289 ± 7	284 ± 9
Cortical drilling	684 ± 11	568 ± 9	541 ± 8	487 ± 9	463 ± 6	439 ± 8	288 ± 12	286 ± 13
Fracture	718 ± 12	570 ± 8	567 ± 10	484 ± 12	480 ± 10	435 ± 8	287 ± 10	286 ± 13
Cast only	567 ± 9	563 ± 6						

Number of animals in each group 10

M = mean

SE = standard error

Table 3b The increase in the height of the proximal growth cartilage of the tibiae on the injured and immobilised side, expressed in micra

	2 weeks M ± SE	6 weeks M ± SE	12 weeks M ± SE	18 weeks M ± SE
	92 ± 3	59 ± 3	4 ± 3	5 ± 2
Periosteal stripping				
Cortical drilling	116 ± 2	54 ± 1	24 ± 2	2 ± 1
Fracture	148 ± 3	83 ± 3	45 ± 2	1 ± 3
Cast only	4 ± 3			

Number of animals in each group 10

M = mean

SE = standard error

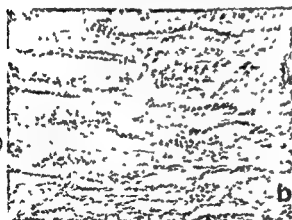


Figure 4a Reticular arrangement of the bony trabeculae in the metaphysis of the injured bone Haematoxylin-eosin $\times 40$ b Metaphysis of the intact tibia Longitudinal arrangement of the trabeculae Haematoxylin-eosin $\times 40$

Figure 5a and b Comparative anteroposterior (a) and lateral (b) roentgenograms of the fractured and control tibiae 18 weeks after the diaphyseal fracture No structural difference in the proximal bone ends



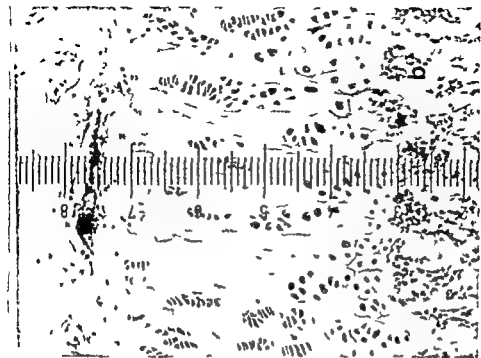
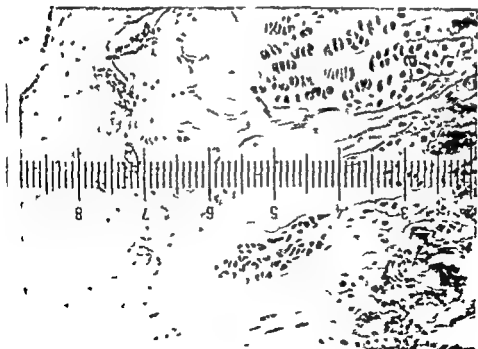


Figure 6a and b. Degenerative changes in the growth cartilage of the injured (a) and intact bone (b).
Haematoxylin-eosin $\times 40$

the age of the animals the growth plate is hardly discernible on either side. The metaphyseal transparency found before in the injured bones had disappeared (Figure 5a and b). The concentration of the ^{51}Cr labelled erythrocytes was not decidedly different on the two sides (Table 1). The activity of the ^{85}Sr showed a significant increase in the 12th week, by the 18th week the difference was no longer significant (Table 2a and b).

No signs of stasis could be observed in the bone marrow. In the growth plate fibrous degeneration of the increased amount of ground substance and the complete disorganization of the columns of chondrocytes could be found bilaterally. The trabeculae of the metaphysis were thin and no active osteogenesis could be seen (Figure 6a and b). The height of the growth cartilage was not significantly different on the two sides in the 18th week (Table 3a and b). These changes could be interpreted as signs of ageing and closure of the growth zones.

DISCUSSION

The results of the investigations described can be interpreted in the following way.

We have found that as a result of the diaphyseal injuries a thick connective tissue layer with fibrous and bony callus developed possibly impairing the circulation through the cortex.

It was proved by Morgan (1959) and Brookes (1971) that the venous sinusoids of the metaphyseal bone marrow are drained especially via the large central vein of the bone marrow and through the emissary vein across the cortex. If the venous circulation is damaged as a result of the diaphyseal injury, stasis will develop in the metaphyseal bone marrow. As also described by Brookes we consistently observed after every kind of bone injury stasis in the metaphyseal bone marrow. The presence of stasis is supported by the elevated concentration of ^{51}Cr labelled erythrocytes found in the metaphyseal bone marrow.

Richards & Brookes (1968) describe in the pH of the tissue as a result of stasis, which enhances the formation of immature bony tissue in the osteon. Although pH was not measured, it was found in the early stage an increase in ground substance, a widening of the germinal and proliferative cells, a significant increase in the height of the cartilage together with more osseous tissue in the metaphysis. Increased metaphyseal transparency in X-ray pictures may be interpreted as presence of immature bony trabeculae, proof of the consequent increased mineralization, the activity of ^{85}Sr by the bone minerals increased significantly.

In the later stage as a sign of improving circulation the stasis disappeared. The normalization of growth and ossification may be interpreted as being a consequence of the return of normal circulation.

In the final stage the height of the cartilage on both sides and the per cent radioactivity did not show significant differences. Radiographic and histological examinations showed signs of closure of the growth zones.

On the basis of the agreement between experiments and the data cited in the literature it can be assumed that the sensitive epiphyseal and metaphyseal reaction to diaphyseal injury to growing limbs is the resultant disturbed circulation and stasis. The investigations showed that the marked changes occurred after fracture, the lesser ones occurring after periosteal injury.

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LONGITUDINAL GROWTH AND DENTAL DEVELOPMENT IN OSTEOSARCOMA PATIENTS

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The body height at 80 years and at the time of diagnosis, as well as the dental maturity, were analysed in a sample of patients with classical and primary osteosarcoma, registered in Sweden between 1972 and 1974, in order to investigate whether these patients have an accelerated body height growth. In contrast to previous reports the height development was found to be normal. The dental maturity was also normal.

Key words: bone tumour, endocrinology, growth, osteosarcoma

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Osteosarcoma is a highly malignant tumour which preferentially occurs in males (sex ratio about 1.5) (Dahlin & Coventry 1967) and which generally appears during the first three decades of life with a peak incidence coinciding with the pubertal growth spurt (Veinfield & Dudley 1962, Price 1958, Dahlin


Coventry 1967, Lockshin & Higgins 1968, Stanton et al 1975, Salzer et al 1976, Larsson & Lorentzon 1974). Price (1958) found a correlation between the time of development of primary bone tumours and accelerated skeletal growth. Such a relationship is also supported by the observation that the predominant tumour location is in the metaphyseal region of the long bones, i.e. close to the growth zones (Dahlin & Coventry 1967). Furthermore, it has been reported that osteosarcoma occurs more frequently in tall individuals (Fraumeni 1967). It should also be mentioned that bone sarcoma in dogs, which resembles human osteosarcoma, is one hundredfold more common in large sized dogs than in smaller ones (Tjalma 1966).

We were not able to confirm the previous

observation of an accelerated body height growth in osteosarcoma patients in a preliminary analysis. Therefore, the present work was carried out in order to study if growth and dental development differ between osteosarcoma patients and healthy individuals.

PATIENTS AND METHODS

All osteosarcoma patients who had been reported to the Cancer Registry at the National Board of Health and Welfare in Sweden during the years 1972-1974 were included in the study. Patients with parosteal tumours or with clinical evidence of metastases upon admission to the hospital were excluded. There were altogether 44 osteosarcoma



osteosarcoma tumours located in the long bones were also included in the study.

Information on body height from birth to the onset of the disease was obtained from the



Figure 1 Age distribution at the time of diagnosis, males (□) and females (▨) ($n = 19$)

children's health centres and from the health services of the schools where body height is registered at regular intervals. Only cases in which two or more measurements were available around the age of 8 years and two or more measurements at the onset of the disease were included in the final analysis. Accordingly 28 of the 47 subjects had to be excluded. In the remaining 19 subjects (9 boys and 10 girls) the height at 8.0 years and the height at the age when the diagnosis was made were calculated by linear interpolation as described by Filipsson & Hall (1975). The height at 8.0 years was compared with the corresponding figure for normal Swedish children given by Taranger (1976). Since the total sample was small and the patients were of different chronological ages at the onset of the disease a standardized normal variable ($(x_i - \bar{x})/SD$) (x_i = the height of the subject, \bar{x} = the normal mean height, SD = the normal standard deviation) was used.

The number of erupted teeth is generally registered annually by the school dentists in Sweden. Information on the number of erupted permanent teeth at different ages from about 7 years of age was obtained for 24 of the subjects

(16 boys and 8 girls). Height registrations were available in 13 of these 24 subjects. Dental maturity was analysed according to the method described by Filipsson (1975). This method can be used for retrospective studies and is based on the finding that the eruption curve of the first permanent molars and incisors has a similar shape in all children. The individual tooth eruption curves, however, are displaced in relation to each other along the age axis. The chronological age at a reference point on the curve can be used to express the dental maturity of each child.

RESULTS

The mean age at the time of diagnosis was 17.4 years ($SD = 7.1$) in the whole group (47 patients), 19.1 years for the males and 14.2 for the females. The corresponding figures for the 9 males and 10 females in whom height registrations were available were 13.2 ($SD = 2.9$) and 13.4 years ($SD = 4.4$) respectively. The distribution of the age at diagnosis in the latter group is shown in Figure 1.

The mean height of the osteosarcoma patients at the age of 8.0 years was 128.4 cm for boys and 128.1 cm for the girls. As seen from Table 1 these values are very similar to those found in normal Swedish boys and girls (Taranger 1976). The difference in height between the patients and the healthy children was small and statistically not significant. The same was true for the height at the onset of the disease. The distribution of the standardized height variables at 8.0 years at the time of diagnosis are shown in Figures 2 and 3. There was a significant correlation between the standardized height at 8.0 years

Table 1 Body height at the age of 8.0 years in osteosarcoma patients and healthy Swedish children

Group		Number of subjects	Body height, cm	
			Mean	SD
Boys	patients	9	128.4	5.1
	controls	114*	128.6	5.3
Girls	patients	10	129.1	5.8
	controls	81*	127.4	5.5

* from Taranger (1976)

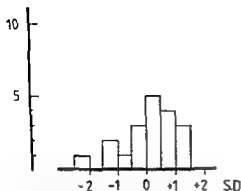


Figure 2 Distribution of the standardized body height ($(x - \bar{x})/S.D.$) at the age of 80 years in subjects with osteosarcoma ($n = 19$)

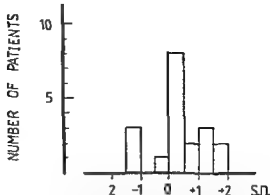


Figure 3 Distribution of the standardized body height ($(x_1 - \bar{x}_1)/S.D.$) at the age of diagnosis in subjects with osteosarcoma ($n = 19$)

the standardized height at the age of diagnosis ($r = 0.88$, $P < 0.001$). As seen from Figure 4 only two subjects deviated more than one SD in their position in relation to normal mean height curve from 80 years to the age of diagnosis.

The mean age at the reference point of the tooth eruption curve was 8.7 years for the boys and 8.4 years for the girls. These figures respond very well to the normal values for Swedish boys and girls (Table 2).

DISCUSSION

In contrast to previous reports (Price 1958, Jernum 1967, Larsson & Lorentzon 1974) the present study has shown that patients with primary and classical osteosarcoma do

not have an accelerated body height growth. This finding is also supported by the observation that the dental development was normal.

The exclusion of subjects having too few height registrations might have had an influence on the results. However, there was no obvious difference between the total material and the analysed group with respect to the age at the onset of the disease. This age, which was 13–14 years, is also in accordance with that found in other studies. The information on body height was more often lacking in males than in females and this could be of significance in a disease with a higher incidence of males. Since the evaluation of the growth data was made separately for the sexes the altered sex ratio in the analysed group can probably be disregarded.

The reports in the literature of a pre-

Table 2 Age at the reference point of the tooth eruption curve in patients with osteosarcoma and healthy Swedish children

Group		Number of subjects	Age at the reference point, years	
			Mean	S.D.
Boys	patients	16	8.67	0.70
	controls	133*	8.75*	0.73*
Girls	patients	8	8.36	0.63
	controls	137*	8.44	0.68*

* from Filipsson (1975)

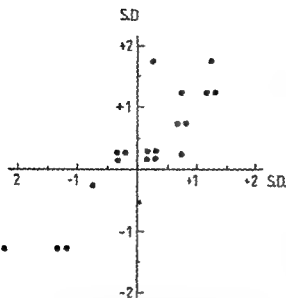


Figure 4 Correlation between the standardized height measurements at 80 years (abscissa) and at the age of diagnosis (ordinate) ($n = 19$)

dominance of tall stature and high growth rate in subjects with osteosarcoma were based on cross-sectional growth data and not on individual growth curves. However, the evaluation of growth data in cross-sectional studies on pubescent children is difficult without information regarding the somatic maturation since there is a wide variation in the timing and duration of the adolescent growth spurt. The change in growth rate around the age of diagnosis observed in some of the patients could therefore very well be attributed to pubertal maturation. None of the three prepubertal patients in the present study showed an accelerated growth at the onset of the disease.

Our findings do not definitely exclude the possibility that the tumours may have a growth promoting effect as suggested on the basis of hormonal studies in osteosarcoma patients (McMaster et al 1975). However, the time period with symptoms prior to diagnosis was only about 3 months which is in good agreement with that observed in previous reports (Broström et al 1980, Sweetnam et al 1971). This period appears to be too short to prove that there is an

accelerated growth rate during the pre-diagnosis growth spurt.

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POSTOPERATIVE INFECTIONS RESULTING FROM BACTEREMIA

An Experimental Study in Rabbits

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The possibility that postoperative infections can result from bacteremia in the early postoperative period was investigated in an animal model. Defects were made bilaterally in the proximal femora of rabbits. On one side the defects were filled with acrylic bone cement. The rabbits were infected with a suspension of *Staphylococcus aureus* either in the wound hematoma or by an intravenous route. The cement implant did not attract infection, as the infections became equally distributed both on the cemented and the uncemented side in the locally as well as in the intravenously inoculated group. The experiment also shows that if bacteria occur in the bloodstream in the early postoperative period there is a high risk of the wound becoming infected.

Key words: bacteremia, bone cement, postoperative complications, wound infection.

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For a long time it has been known that traumatized areas can become the seat of a blood-borne infection (Starr 1922, Winters & Allen 1960, Gerszten et al 1970). Acute hematogenous osteomyelitis has been reported to follow closed fractures (Canale et al 1975, Watson & Whitesides 1976). The surgical trauma has, however, not been considered in earlier discussion. The present study investigates the susceptibility of an operative wound to hematogenous infection.

MATERIALS AND METHODS

A standard operation was performed on the right and left femora of 14 male New Zealand rabbits (weight 1.5-2.5 kg). Anesthesia with barbiturate (Nembutal, Abbott Laboratories) and ketamin chloride (Ketalar, Parke-Davis & Co.) was used. Skin incision and draping as in an ordinary

operating theater was applied. A longitudinal incision exposed the lateral aspect of the proximal femur.

On the left side no further procedures were performed. The wound was closed with absorbable polyglycolic acid sutures (Dexon, Davis and Geck Ltd.).

On the first postoperative day 1 ml of a bacterial suspension containing a *Staphylococcus aureus* strain (Wood 46) was injected into an auricular vein in seven rabbits. Simultaneously seven rabbits had 0.5 ml of the same bacterial suspension injected into the postoperative hematoma. Daily injections were continued for 3 days. The experimental period was 1 week in the group receiving direct inoculation and 2 weeks in the intravenously inoculated group.

The *Staphylococcus aureus* strain (Wood 46) is known to be able to cause septic arthritis (Lundberg 1969) and is sensitive to most commonly used antibiotics. After one animal passage the strain was tested for desoxy-

Table 1 Details of the experiment

	Animals receiving	
	Direct inoculation	Intravenous inoculation
■	7	1
Initial body weight (g)	2730 ± 260	2710 ± 220
Final body weight (g)	2500 ± 120	2110 ± 430
Experimental period	1 week	2 weeks
Average number of bacteria per dose	3.2×10^9	7.2×10^8

ribonuclease and coagulase and phage typing was done according to standardized methods. The strain was then used in the experiment.

Autopsy was performed after 1 or 2 weeks, respectively, according to a detailed scheme and a new set of sterile instruments was used for each anatomical layer. A bacteriologic specimen was obtained from each location using a sterile cotton stick. Samples were taken from the surgical areas blood, lungs, kidneys, liver, spleen and heart. The specimens were cultured on blood agar and hematin plates and incubated for 12 hours at 37° C, if necessary the plates were incubated for another 24 hours. Colonies suspected of being *Staphylococcus* were tested first for deoxyribonuclease and then for coagulase and all positive colonies were phage typed.

RESULTS

The general condition of the rabbits receiving bacteria intravenously was severely affected and they had a greater loss of body weight compared with those receiving direct inoculations into the wound hematoma (Table 1). During the first 24-48 hours of the experiment, the intravenously infected animals did not consume measurable quantities of food or water. Two rabbits died on the 6th and 7th post-inoculation day, respectively (Table 2). One rabbit seems to have died of septicemia with

Table 2 Macroscopic infections at autopsy (= abscesses)

	Rabbit no.	Kidney	Lung	Liver	Right femur (cement)	Left femur
Animals receiving direct inoculation	1	—	—	—	—	—
	2	—	—	—	—	—
	3	—	—	—	—	—
	4	—	—	—	—	—
	5	—	—	—	Abscess	—
	6	—	—	—	Abscess	—
	7	—	—	—	—	—
Animals receiving intravenous inoculation	1	—	—	—	Abscess	Abscess
	2	—	—	—	—	—
	3†	—	—	—	—	—
	4	—	—	—	—	—
	5†	—	—	—	Abscess	—
	6	—	—	—	—	—
	7	—	—	—	—	—

Table 3 Results of the bacteriologic analysis

	Rabbit no	Heart blood	Kidney	Lung	Liver	Right femur (cement)	Left femur
Animals	1	—	—	—	—	—	—
Surviving	2	—	—	—	—	—	S.A.
Rect	3	—	S.A.	—	—	—	—
Inoculation	4	—	—	—	—	S.A.	—
	5	—	—	—	—	—	S.A.
	6	—	—	—	—	S.A.	S.A.
	7	—	—	—	—	S.A.	—
Animals	1	—	S.A.	G-rod	—	—	S.A.
Surviving	2	—	S.A.	—	—	S.A.	S.A.
Intravenous	3	E coli	E coli	E coli	E coli	E coli	E coli
Inoculation			S.A.				
	4	—	S.A.	—	S.A.	S.A.	S.A.
	5	S.A.	S.A.	S.A.	S.A.	S.A.	S.A.
	6	—	S.A.	—	—	S.A.	—
	7	—	—	E coli	—	S.A.	S.A.

A - *Staphylococcus aureus* of the experimental strain (Wood 46) proved by phage typing

Staph. aureus strain whereas in the other 3) dissemination with *E. coli* had occurred. None in the directly inoculated group died.

Autopsy performed after the experimental period on the remaining rabbits revealed macroscopic signs of infection in the area of operation in half the cases, but only in seven rabbits had indisputable abscesses formed. The macroscopic infections were evenly distributed between the two experimental groups. Apart from the area of surgery, no obvious macroscopic infection was found (Table 2). The bacterial evaluation (Table 3) showed that at the end of the experiment bacteremia had disappeared in all the intravenously infected rabbits. The experimental strain of *Staph. aureus* was, however, frequently isolated from the kidneys.

In four intravenously infected rabbits, *Staph. aureus* was found around the cemented defect of the femur and in four around the uncemented femur defect. Thus, only two of the operated femurs were found to be sterile in the intravenously infected group.

In the group of seven rabbits that had been directly inoculated with *Staph. aureus* at the femur defect, three defects with and three without cement were infected at the end of the observation period. Obviously, the cement was in neither group associated with a change in the incidence of infection.

DISCUSSION

Staphylococcus aureus (Wood 46) was used in this experiment because of its known potentiality to cause bone and joint infection (Rigdon 1942, Lindberg 1969, Norden & Kennedy 1970) and the possibility of identifying the experimental strain according to the phage type. The dispersion of *Staphylococcus aureus* in the blood resulted in a considerable death rate in these series. The experimental period of 2 weeks was chosen in order to allow the bacteremia to disappear before sacrifice. After that period no positive blood culture was found but a remarkably high number of cultures from the kidneys were

positive. Continuation of bacteremia as a kidney infection has been reported earlier by Thompson & Dubos (1938), Norden & Kennedy (1970) and Elson et al. (1977).

This experiment shows that if bacteria occur in the bloodstream during the early postoperative period there is a definite risk of wound infection. Surgery often necessitates prolonged intravenous support and in some cases urinary catheterizations are performed. This involves a risk of bacteremia (Maki et al. 1973, Donovan et al. 1976, Svanbom 1979) and will be of particular significance in artificial joint replacements because of the known difficulties in overcoming the infection in such cases (Creuss et al. 1975, D'Ambrosia et al. 1976, Downes 1977, Ahlberg et al. 1978).

Howe (1968) proved that a silk suture implanted in a surgical wound in guinea pigs did not lead to a higher infection rate after a period of bacteremia than in control wounds. The rate of infection found in this experiment is in agreement with that found in an experiment by Elson et al. (1977) in which an infection rate of 70 per cent was noted in rats after intravenous injection of *Staph aureus*. However, no conclusion as to whether the bone cement or the operative trauma alone caused wound infection can be drawn from their series. In both the series mentioned (Howe 1968, Elson et al. 1977) bacteremia occurred during a period when wound bleeding must have been present to some extent. This is not likely to be the case in the present experiment, thus indicating that it was the traumatized tissue which tended to attract hematogenous infection. In our experiment the cement implant obviously did not lead to higher infection rates in the locally or the intravenously inoculated group. The size of the infection dose is of decisive importance to the development of a clinical infection. This factor is difficult to determine in bacteremia since the bacteria may multiply in the blood during a short period of time and then disappear. But if bacteremia occurs during the early postoperative period a postoperative infection is likely to occur.

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SOFT TISSUE INTERPOSITION ARTHROPLASTY FOR OSTEOARTHRITIS OF THE CARPOMETACARPAL JOINT OF THE THUMB

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A soft tissue interposition arthroplasty for carpometacarpal osteoarthritis of the thumb is described. Thirty-seven joints in 32 patients were operated on. The results with regard to pain, strength and mobility are recorded. In 34 cases the patients reported considerable improvement after the operation and the majority of the patients could resume their usual work. Only minor complications occurred.

Key words: carpometacarpal osteoarthritis, interposition arthroplasty, thumb.

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Osteoarthritis of the carpometacarpal joint of the thumb occurs most frequently in women after the menopause (Aune 1955). It may be a sequel to Bennett's fracture, but in most cases the aetiology has not been established. However, reduced stability of the joint due to hypermobility seems to be a predisposing factor (Aune 1955, Eaton & Littler 1973). When the arthritic changes progress they may result in a painful thumb with decreased mobility and strength.

In the early stage of the arthritis, rest and conservative treatment with splinting and corticosteroid injections can be helpful. In cases with advanced degenerative changes amputation is the only means of improving the condition. The following types of operations have been used: Excisional arthroplasty of the trapezium (Gervis 1949, Murley 1960, Weinmann & Lipscomb 1967), fusion of the trapeziometacarpal joint (Leach & Bolton 1968, Mattsson 1969, Eaton & Littler 1969, Jensen & Carstam 1970, Stark et al. 1977), silicone implant arthroplasty (Swanson 1972, Bessler 1973, Dickson 1976, Ferlic et al.

1977, Haffajee 1977, Lister et al. 1977) and total prosthesis (Caffinière 1973, Krenschek et al. 1978).

The aim of the present paper is to present an additional and easy method which is applicable in most cases of carpometacarpal osteoarthritis of the thumb.

METHOD

The operation is performed under regional anaesthesia. A slightly curved dorsal incision is made from the styloid process of the radius to the middle of the first metacarpal bone. The superficial branch of the radial sensory nerve is identified and preserved and the trapeziometacarpal joint localized. A soft tissue flap consisting of subcutaneous adipose tissue and connective tissue, is dissected from the anatomical snuff-box. The flap has a breadth of 1.4-2 cm and a length of 3-3.4 cm with the base located outside the proximal end of the first metacarpal bone (Figure 1). During the dissection the radial artery is identified and care is taken not to damage this structure. Then the capsule of the trapeziometacarpal joint is opened the full breadth

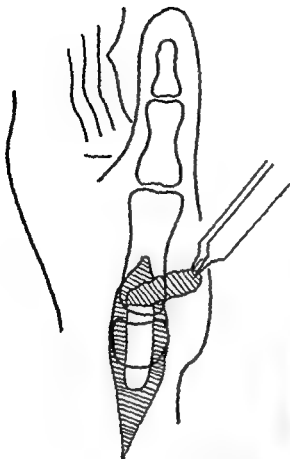


Figure 1 The soft tissue flap before the interposition

of the joint. The capsule is dissected from the bones leaving a collar of 3–4 mm on each side. By pulling the thumb the trapeziometacarpal joint can be opened. Osteophytes and cartilage are removed until an opening of approximately 3–4 mm is obtained while pulling the finger slightly. The soft tissue flap is now interposed between the trapezium and the metacarpal bone by means of a resorbable suture. The suture is pulled through the tip of the flap and both ends of the suture are passed down through the opening and through the skin on the volar side of the hand where they are knotted over a small gauze tampon. The interposition can be supplemented with a part of the abductor pollicis longus tendon preserving its distal insertion. In the present series this was done in 23 cases (62 per cent). Finally the joint capsule is closed using non resorbable sutures. The thumb is immobilized in abduction with an elastic bandage for 3 weeks after which the patients begin active exercises (Figure 2a, b).

MATERIAL

During the period 1966–1977 34 patients were operated on. The main indication for the operation was pain which had not responded to conservative treatment. The average duration of symptoms prior to the operation was 3 years and 8 months.

At the follow-up examination one patient died and one had moved abroad. The series includes the remaining 32 patients. In five patients both thumbs have been operated on, making a total of 37 operations. The average follow-up period was 5 years and 7 months, minimum follow-up period 15 months.

The age of the patients at the time of operation varied between 21 and 70 years with a mean of 55 years. There were 3 men (9.4 per cent) and 29 women (90.6 per cent). All the women and the one man had idiopathic osteoarthritis. The two



Figure 2 Osteoarthritis of the carpometacarpal joint of the thumb (a). The same patient after operation (b)

Table 1 The metacarpal angle after soft tissue interposition arthroplasty for osteoarthritis

Metacarpal angle	Total no of thumbs	No of thumbs with hyperextension in the metacarpophalangeal joint
> 40°	5	0
30°-40°	8	3
20°-30°	12	8
< 20°	12	11
	37	22

developed osteoarthritis after Bennett's fracture.

The average time of hospitalization was 3 days. One patient developed a wound infection postoperatively but she recovered without further surgery. Another patient sustained a post-traumatic sympathetic dystrophy. She was treated with stellate blocks and was immobilized for 4 weeks after which the symptoms disappeared.

RESULTS

The criteria described by Kessler (1973) for the assessment of results were the ones used in the present material, in a modified form.

In Twenty-nine joints (78 per cent) were completely free of pain. In five joints (14 per cent) mild and periodic pain occurred. These patients especially complained of pain after hard work. In the remaining three joints (8 per cent) there were still significant and rather constant pains. The pain in these three patients could be explained by arthritis in the other articulations of the trapezium. A pantrapezium arthritis was not present in the other patients in the material.

Pinch test The strength of the thumb was tested by asking the patients to pinch a sheet of paper firmly between the thumb and the index finger. A normal pinch when the sheet could not be withdrawn was shown in all but one case.

Ability to touch the base of the fifth finger In the present series 32 thumbs (87 per cent) could reach the centre of the base of the little finger. Two fingers could be opposed to a distance of 1 cm, two fingers to a distance of 2 cm and one to a distance of 4 cm. The last patient had arthrodesis in the metacarpophalangeal joint of the thumb.

The metacarpal angle The angle between the first and the second metacarpals in adduction and in radial abduction was measured in radiographs taken with the hand in pronation on a flat surface. The angle was more than 40° in 5 cases, between 30° and 40° in 8 cases, between 20° and 30° in 12 cases and below 20° in 12 cases. As shown in Table 1 a reduced angle is combined with hyperextension in the metacarpophalangeal joint of the thumb.

Personal evaluation All but the three patients with pantrapezium arthritis reported considerable improvement after the operation.

One woman stopped working outside the house after the operation, three patients changed to an easier job, while the remaining 28 patients resumed their usual work. In eight cases the patients had some difficulty handling a small object like a sewing-needle.

DISCUSSION

None of the operations designed for treatment of osteoarthritis of the thumb has resulted in a stable, painless thumb with satisfactory strength and reasonable movement in all cases. The excisional arthroplasty of the trapezium is simple and provides a pain-free and mobile thumb, but the strength is decreased and the joint rather unstable (Murley 1960, Weilby 1971). Fromson (1970) and Buck-Gramcko (1972), however, combined the excision of the trapezium with insertion of tendon graft interposition material and reported good results. Fusion of the trapeziometacarpal joint

creates good stability but the mobility is reduced. In addition, fusion takes a long time and pseudarthrosis often occurs (Mattsson 1969, Weilby 1971). Stark et al (1977) did not find that fusion predisposed to painful arthritis of the trapezioscapoid joint. The interposition arthroplasty introducing silicone into the joint has in some materials given good results (Kessler 1973, Dickson 1976, Aschworth et al 1977), but Crawford (1977) at a follow-up found chronic synovitis and torn and dislocated prostheses. The most frequently used method is excision of the trapezium and replacement with a silicone prosthesis. In ideal cases this method provides good stability and motion as well as freedom from pain. However, the common problem with the trapezium arthroplasty has been subluxation and dislocation of the trapezium implant, which has been described in up to 32 per cent of the operated joints (Weilby & Sendorf 1978). The number of dislocations can be reduced by improved operation technique including tendinous reinforcement of the capsular repair (Swanson 1972, Ferlic et al 1977, Haffajee 1977, Lister et al 1977), or stabilization of the implant by incorporation of a local tendon strip (Eaton 1979). The total prosthesis is a promising method for operation of carpometacarpal arthritis of the thumb, but only small series have been published (Caffinière 1973, Kremchek et al 1978).

The present method for operation of disabling osteoarthritis of the thumb is technically simple and in most cases the patients were effectively relieved of pain. The abduction of the thumb was somewhat reduced and a compensatory hyperextension of the metacarpophalangeal joint had developed. However, the function of the thumb was sufficient for the patients to perform their usual work except for the heaviest procedures, and in no cases was the thumb unstable. The method was not very suitable when the carpometacarpal arthritis was part of a pantrapezium arthritis, which in the present series occurred in 3 out of 37 cases. It is suggested that pain in these

patients derived from the trapezium joint. Kessler (1973), among 40 patients with osteoarthritis of the carpometacarpal joint of the thumb, had only four with associated osteoarthritis of the trapezioscapoid joint, while Swanson (1972) found additional arthritic changes in the second trapeziometacarpal joint in 82 per cent, in the trapeziotrapezoid joint in 34 per cent and in the trapezioscapoid joint in 10 per cent.

The operation method in some extent to be chosen with due regard to the patient's work. Thus fusion may be the best procedure of choice in those patients in whom stability and strength are very important. For the patient not doing heavy work the present method is a simple alternative to the other available methods. In contrast to the previously described soft tissue interposition methods (Fromson 1970, Buck-Granic 1972) it is not necessary to remove the trapezium, which is the keystone of the thumb arch (Lister et al 1977). Other advantages are that foreign material in the thumb is avoided and the possibility of a future revision operation is not precluded.

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COLLAGEN-INDUCED PLATELET AGGREGATION AND BLEEDING TIME IN ADOLESCENT IDIOPATHIC SCOLIOSIS

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Collagen is the main supportive protein of connective tissue. Another of its functions is the initiation of haemostasis by activation of the platelets. It has been suggested that collagen is abnormal in idiopathic scoliosis. The present study lends further support to this view: collagen of fascia specimens from patients with adolescent idiopathic scoliosis was found to aggregate platelets less readily than collagen from non scoliotic controls and suspensions of fascia from patients with adolescent idiopathic scoliosis contained more collagen than those from the controls. The collagen abnormality is probably also reflected in a prolonged bleeding time. The changes in the collagen in patients with scoliosis persist at least for some years after the cessation of growth.

Key words: bleeding time, collagen, scoliosis

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the possible underlying causes of idiopathic scoliosis, only hereditary factors are now widely accepted, but nothing definite is known of their mode of action (Cowell et al 1972, Harrington 1977, Wynne-Davies 1978). In the last decade a disturbance of connective tissue has been discussed as a possible causal factor, it having been observed that scoliosis is unusually common in patients with defective collagen, e.g. in Ehlers-Danlos syndrome and in Marfan's syndrome (McKusick 1972).

Collagen is the most important supportive factor of connective tissue. Another important function of collagen is the initiation of haemostasis by activation of the platelets (Hugues 1960). The connection between collagen defects and impaired haemostasis has been described in different

types of Ehlers-Danlos syndrome (Karaca et al 1972, McKusick 1972, Pinnell et al 1972) and in scurvy (Caen & Legrand 1972). This paper concerns possible defects of the collagen in adolescent idiopathic scoliosis and the influence of collagen on bleeding time.

MATERIAL

The material consisted of 14 females and one male with adolescent idiopathic scoliosis with a range of curves between 50°-100° according to Cobb. The patients were operated on in a one-step procedure with correction and internal fixation according to Harrington and posterior fusion. Biopsy specimens were obtained from the fascia of the longitudinal dorsal muscles on the convex as well as on the concave side of the curve. Ten age-matched patients (three females and seven males)

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Table 1 Results of the analysis of collagen from patients with idiopathic scoliosis and controls. The first figure in brackets denotes the mean values for control samples obtained from back muscle fascia, the second figure, mean values for the other control samples. CC = minimal concentration of collagen in platelet rich plasma (PRP) that induces platelet aggregation

No	Age years av \pm s.d	Collagen in suspension mg/l av \pm s.d	CC mg collagen/l PRP av \pm s.d	Geometric mean and range	CC % av \pm s.d
Scoliosis 15	18 \pm 4	130 \pm 70	32 \pm 24	2.5 (1.3-8.4)	70 \pm 5
Controls 10	19 \pm 6	50 \pm 20	0.8 \pm 0.4	0.7 (0.2-1.4)	10 \pm 1
(5 + 5)	(16-21)	(50-50)	(1.0-0.6)		(20-1)
t-test for difference between means		$P < 0.01$	$P < 0.01$	$P < 0.001$	$P < 0.01$

operated upon for disc herniation, spondylolisthesis or fractures of the extremities served as controls (Table 1). In five cases the specimens were obtained from the fascia of the same muscles, as in the scoliotic group, in the remaining five, from the muscle fasciae of the extremities.

The bleeding time was determined in 68 patients, aged 11 to 32 years (mean 18 \pm 6 years), operated for scoliosis, and in 24 healthy non-scoliotic controls, aged 11 to 16 years (mean 13 \pm 2 years).

METHODS

Collagen suspensions were prepared as described in detail elsewhere (Udén & Nilsson 1978). In short, the pieces of fascia were scraped clean, freeze-dried in a vacuum and homogenized in ice-cold 8.35 mM acetic acid for 60-90 seconds. The suspension was stored at -60°C . Before being used it was rehomogenized and centrifuged at 1200g for 30 minutes at $+4^{\circ}\text{C}$. The supernatant which was clear was immediately used to determine the platelet aggregating power of the collagen. The amount of collagen in the supernatant was calculated from the content of hydroxyproline measured by a modified Woessner method (Udén & Nilsson 1978).

The platelet aggregation was assessed photometrically. A Payton Dual Channel Aggregation Module was used. It includes constant magnetic stirring and constant recording of the transmission. The lowest concentration of collagen in platelet-rich plasma (PRP) that induced platelet aggregation was called the critical concentration (CC) - high CC is associated with low aggregating power (Udén & Nilsson 1978). PRP

was obtained from healthy volunteers. The responsiveness of PRP even from healthy persons varies. The CC of the collagen suspension in scoliotic patients and from controls was expressed in μg .

The statistical methods used were the t-test for differences between means and Pearson linear correlation test.

RESULTS

The collagen content of the suspension from patients with scoliosis was significantly higher than that from controls, and the collagen from patients with scoliosis aggregated platelets only one-fifth as efficiently as collagen from the controls (Table 1). The first figure in brackets in Table 1 denotes the mean value found for the control samples obtained from the back muscle fascia as in the patients with scoliosis. The second figure, the corresponding value for the other controls.

Platelet aggregation and the concentration of collagen in the suspension did not vary with the patients' age ($r = -0.2$ and $r = 0.1$ respectively). However, in the scoliotic patients a significant correlation ($P < 0.01$) existed between CC and collagen concentration in the suspension ($r = 0.68$), which means that

e easily the collagen was dissolved the it aggregated platelets. There was no ificant difference in collagen content in suspensions or the platelet aggregation erties with sex

he Ivy bleeding time in 68 patients with osis was 9.6 ± 2.6 (av \pm s.d) minutes 7.9 ± 1.7 (av \pm s.d) minutes in the ols. The difference was significant ($P < .05$) There was no correlation between age bleeding time ($r = 0.009$)

DISCUSSION

lagen is the only constituent of connective ue that has any appreciable tensile ngth (Grant & Prockop 1972a), and defects collagen can cause scoliosis. For instance, osis can be provoked in animals by β -no-propionitrile (Pons  ti & Baird 1952), ch inhibits the first reaction necessary for r-molecular cross linking of collagen ant & Prockop 1972b) Also in a highly red line of chickens with a readily soluble agen there was an incidence of scoliosis of per cent (Riggins et al 1977)

Also in idiopathic scoliosis collagen ormalities are on record. Francis et al 77) tested the resistance of extracted ymeric skin collagen against depolymeriza- y by NaOH. This resistance was decreased most patients with adolescent idiopathic losis as compared with non-scoliotic ols. The authors felt that a decrease in ymeric collagen resistance reflects a cor- ponding decrease *in vivo* of the number or er types of collagen cross-links. The ormality was greatest in the youngest ents.

It has been reported from Australia that ges in the collagen content of scoliotic os are related to the degree of scoliosis and c mobility (Taylor et al 1976) To dis- quish between primary and secondary ets the authors tested the extractability of flagen by pepsin across thirteen zones of etal and scoliotic discs and found a signifi- cant difference between patients with

scoliosis and the controls. The values did not vary with the side of the curve from which a given specimen had been obtained and could thus not be related to mechanical loading (Bushell et al 1978)

Other authors have found no alterations in collagen from patients with idiopathic scoliosis, for instance, Nordwall compared tendons and ligaments from 40 patients with idiopathic scoliosis with corresponding specimens from 20 patients with paralytic or congenital scoliosis. He tested the biomechanical properties, the shrinkage on heat denaturation and the collagen content. He found no significant difference between the groups (Nordwall 1973)

Bradford et al (1977) studied skin fibroblasts in culture. They compared patients with idiopathic scoliosis with seven age-matched controls and found no significant difference in any parameter tested (cell layer, extractability with salt or acetic acid and hydroxyproline to proline ratio) except that the fibroblasts from the scoliotic patients had a lower hydroxyproline to proline ratio in the non-dialyzable media (Bradford et al 1977). The authors concluded that idiopathic scoliosis is not a generalized connective tissue disorder.

A perusal of the literature failed to reveal any studies of the platelet aggregating properties of collagen from patients with idiopathic scoliosis. Our finding that the collagen in adolescent idiopathic scoliosis has a decreased platelet aggregating power might be an artefact caused by the preparation of the collagen suspensions, for instance, interaction of the state of aggregation of the collagen itself due to storing. However, the suspensions were all used within 2 hours and a correction for changes with time is included in the method (Ud  n & Nilsson 1978).

We used a crude suspension of collagen in the test of the platelet aggregating power. Otherwise the collagen loses most of its aggregating power (Ud  n & Nilsson 1978). Using a suspension one can also obtain information about the insoluble part of the collagen, though it is then not possible to

assess the percentage of the total collagen that is solubilized, but it was clear that the suspension of fascia from patients with adolescent idiopathic scoliosis contained more collagen than corresponding suspensions from non-scoliotic controls and that the collagen had a decreased platelet aggregating power *in vitro*. A possible explanation for these findings is an altered cross-linking of the collagen as in Ehlers-Danlos syndrome type VI, which is characterized by scoliosis and a bleeding tendency and in which the basic defect is a decreased cross-linking due to lack of lysin-hydroxylase (Pinnell et al 1972). Another possibility is a decreased content of collagen type III, which has an increased platelet aggregating power (Balleisen et al 1975), or an otherwise altered structure of the collagen. However, the main point is that there are significant differences in the scoliotic fascia, which speak in favour of collagen being involved in the development of idiopathic scoliosis.

The prolonged bleeding time also supports the concept of an *in vivo* defect of the platelet aggregating power of the collagen. The bleeding time was not so prolonged as to cause any undue bleeding during the operation.

Inter-individual comparison of collagen-induced platelet aggregation is best based on identical anatomical structures (Udén & Nilsson 1978). In five of our controls this was not the case. However, they did not differ a great deal from the other controls, and the differences between the patients with scoliosis and the two subgroups were still significant ($P < 0.05$). About one-third of the patients with scoliosis were adults and since they did not demonstrably differ from the younger patients it would appear that the collagen defect persists even into adulthood.

The methods used in this paper and in the above cited papers give indirect information about mature collagen and may reflect different qualities of this complex molecule. It is therefore not surprising that abnormalities are found in some investigations but not in others. For instance, a defect of the collagen

due to some hormonal influence increased rate of synthesis is not to be observable in a fibroblast culture.

Our knowledge of the role of collagen in scoliosis is still very limited. The basic defect or defects are not known, but, judging from our present knowledge, it seems likely that collagen is at least involved in the development in some cases of adolescent idiopathic scoliosis.

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GROWTH RELATED HORMONES IN IDIOPATHIC SCOLIOSIS

Endocrine Basis for Accelerated Growth

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In a total of 95 children with idiopathic scoliosis and 60 controls between the ages of 7 and 17 years, a prospective study of hormones related to growth and maturation was carried out.

The pituitary release mechanism for growth hormone was evaluated

by the use of a growth hormone stimulation test. The test was carried out in the morning, and the children were fasted overnight. The test was performed in the morning, and the children were fasted overnight. The test was performed in the morning, and the children were fasted overnight.

The girls with idiopathic scoliosis had a significantly higher response to the growth hormone stimulation test than had the controls between the ages of 7 and 12 years whereas no significant difference could be found for the older girls. In girls with a skeletal age between 9 and 12 years a significantly higher mean serum level of testosterone was found ($P < 0.05$). No significant differences could be demonstrated for the remaining hormones.

Growth hormone and testosterone are the most important growth factors in prepubertal and pubertal children. Thus, the present findings suggest a hormonal basis for the increased stature in children with idiopathic scoliosis which has previously been reported.

Key words: adolescence, growth, growth hormone, idiopathic scoliosis, sex hormones

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It is an accepted clinical observation that scoliosis deteriorates during periods of rapid growth and thus has been documented by various authors (Calvo 1957, Duthie 1959, Jones 1976, Duval-Beaupère et al 1970). Adolescent idiopathic scoliosis is most often diagnosed in girls 11-13 years of age (Willner 1972), i.e. during one of the most intensive growth periods of life. These observations indicate a close relationship between longitudinal growth and the development of idiopathic scoliosis (IS). Willner (1972) found that girls with IS were significantly taller than healthy controls even without making

correction for the deformity. He could not identify the prepubertal growth spurt among children with IS and he suggested that a period of increased height velocity had occurred prior to the diagnosis, indicating a different growth pattern in these children.

In 1967 Neugebauer (1974) introduced the so-called "combined brace and hormone therapy" and achieved at least a temporary reduction of the scoliosis on terminating growth by oestrogen therapy.

Several investigators have carried out biochemical analyses in an attempt to find evidence for more intensive growth in

Table 1 Number of patients included in the study

	Female	Male	Total
Scoliotics (IS)	84	11	95
Controls (C)	46	14	60
	130	25	155

patients with IS than in healthy children. However, the results of these investigations, in particular those from growth hormone studies, are not in agreement with one another. Misol *et al.* (1971) were not able to find any difference in growth hormone (GH) levels between IS patients and controls, whereas Willner *et al.* (1976) found higher mean fasting levels of GH in scoliotics and also higher levels of somatomedin A in the same group. This latter finding was not confirmed by Spencer & Zorab (1977).

Testosterone is an important growth factor during adolescence (Tanner 1973, Wilkins 1965), therefore it is interesting that the investigation of Edelmann & Gupta (1974) indicated remarkably high levels of male sex hormones in the IS patients. In addition, the increased urinary excretion of total hydroxyproline in the IS patients (Zorab *et al.* 1971) could be linked with more intensive growth.

Several hormones influence growth and maturation in pre-pubertal and pubertal children. The objective of this study was to analyse some of the most relevant hormones and try to identify potential differences between children with and without IS. The importance of GH and testosterone is evident, but the selection of other "relevant" hormones is a matter for discussion. Therefore, a representative selection of such hormones has been included which, according to the literature, may influence physical development.

PATIENTS AND METHODS

During the period April 1977–May 1979, a prospective study of 155 consecutive patients was carried out. A total of 95 patients with pro-

gressive idiopathic scoliosis and 60 examined between the ages of 7 and 17 (Table 1). Idiopathic scoliosis was defined as structural scoliosis without a known or without association with other disease cases the deformity had been diagnosed at age of 5 years (in the majority of cases 1–3 years of age) and progression of the curve always be documented. No distinction was made between juvenile and adolescent idiopathic scoliosis. The patients were treated for scoliosis curves ranging from 72 degrees (Cobb 1948) at the time of examination, the mean scoliosis angle was 34.5 with a standard deviation of 12.1 (34.5 ± 12.2). The control group consisted of patients attending the hospital for various paediatric disorders other than IS (Table 1).

Height and sitting height were measured in all patients. None of the patients in the study group or in the control group suffered from a disease where hormonal disorders are suspected. All patients were hospitalized and blood samples were collected, either before or after some kind of conservative treatment or in observation. None expected surgical operation. Blood samples were collected by the same investigator who also talked to every child before the test.

The purpose and nature of the study were carefully explained to the patients and parents. Sixty patients consented to participate in the study and the control group. The blood samples from the patients were taken as part of the clinical investigation.

The first part of the study was designed to evaluate the response to a GH stimulation test, in which the effect of propionolol and L-dopa release was compared in the two groups.

Table 2 Control group Diseases and number of patients

Diseases	Number of patients
Cong. dislocation of the hip	10
Cong. scoliosis/kyphosis	4
Scheuermann's disease	1
Neuromuscular scoliosis	2
Anisomelia	1
Other spine deformities	1
Cong. club foot	2
Spondylolisthesis	2
Anteversion of fem. neck	1
Perthes' disease	1
Others	1

Table 3 Hormones investigated. Number of girls in each group. The differences in sample are random and purely due to technical circumstances (for FSH and LH, see text)

Hormone	No. of patients	
	IS	C
Growth hormone		
GH	84(11)	46(14)
Testosterone	61(7)	44(13)
Hormone binding globulin (SHBG)	78(10)	40(14)
Radioiodine	59(7)	44(12)
Thyroxine	50(8)	23(8)
Prolactin	66(10)	28(13)
Oestradiol	60(6)	24(11)
	26(4)	
	25(4)	

1974). All 155 patients are included in this study. After an overnight fast of at least 8 hours a cannula was inserted into an antecubital vein and opened during the test with heparin solution (heparin 100 IU/ml NYCO). The first blood sample was collected shortly after the insertion of cannula and then a single dose of propranolol (Icilin® ICI) 1 mg/kg body weight was administered orally. Sixty minutes later a second blood sample was collected and 10 mg/kg body weight of L-dopa (Eldopar®, WEIFA) was given. During the following 120 minutes blood samples were obtained every 30 minutes. The patients remained recumbent throughout the procedure. With exception of nausea in some of the patients no complications occurred during or after the test either in the IS or the control group.

The serum GH was determined by radioimmunoassay (Norman & Turtur 1968; Sand & Torjesen 1973). The response to the GH stimulation test was evaluated in the different age groups by measuring the mean peak response by drawing the number of individuals with a response over a given "threshold" and by calculating the mean area under the time-response curve which was called the integrated concentration of GH (ICGH).

In the first series of 29 IS patients and 2 controls the test period lasted only 150 minutes. For technical reasons the GH value at time 0 is missing for 4 other IS patients. Thus, in order to avoid the exclusion of these 35 patients,

ICGH was calculated for the time 60-150 minutes in all patients as well as for the whole test period (0-180 min) where possible. Good correlation was found between the two areas in all

the patients with full-time testing (regression coefficient = 0.8).

Blood samples to determine the serum levels of the other hormones were obtained together with the first sample for GH analysis (time 0 of the stimulation test). The number of hormone tests in each group of IS patients and controls (C) is given in Table 3. Testosterone was determined by radioimmunoassay after paper chromatographic isolation according to Naess et al. (1976). Sex hormone binding globulin (SHBG) determinations were performed by equilibrium dialysis as described by Aakvaag et al. (1978), thyroxine and cortisol by radioimmunoassay according to the description by the same authors. The other hormone assays were carried out according to previous publications for FSH and LH (Sand & Torjesen 1973; Torjesen et al. 1974), prolactin (Ruiz et al. 1977) and oestradiol (Fosså et al. 1977). The values of FSH and LH in the first 30 IS patients were all normal so no further samples for this purpose were collected.

The skeletal age was determined in all patients by the Greulich & Pyle method (1970) and all results were evaluated according to skeletal as well as chronological age.

For the evaluation of the GH data the girls were divided into age groups using the age of 12 years as the 'start of puberty'. For the evaluation of thyroxine, prolactin and cortisol 13 years of age was chosen as the "turning point" in order to avoid comparison of very different sample sizes.

The data analysis was run on a Digital Equipment Corporation "DEC-10" computer, using standard statistical routines. Significance testing was carried out using the Mann-Whitney U-test. However, the Welch test (Armitage 1974) was used in cases with more than 25 per cent difference in standard deviations and where sample sizes were larger than 20 and 40, respectively. The two-tailed test was used in all cases.

RESULTS

Growth hormone The female patients with IS in all age groups had a more marked response to the stimulation test than had the controls, but the number of positive responses ($\text{rise} > 5 \mu\text{g/l}$) was not significantly different in the two groups (84 and 82 per cent in the IS group and the control group, respectively). Among the IS patients the majority of those with no response (13/15) had high fasting values ($> 7 \mu\text{g/l}$), whereas in the control

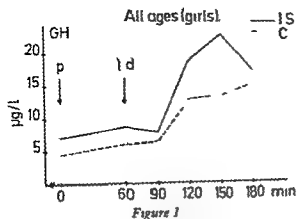


Figure 1

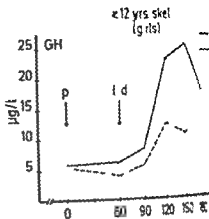


Figure 2

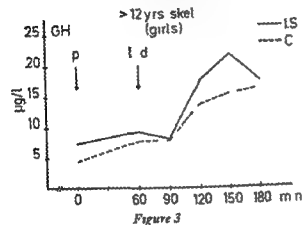


Figure 3

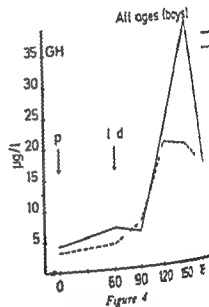


Figure 4

Figures 1-4 Mean GH response curves for scoliotics and controls after stimulation with propanolol (p) and L-dopa (1-d) (for standard deviation values see tables)

group only 3 out of 8 "non-responders" had fasting values $> 7 \mu\text{g/l}$. There was no significant difference in mean fasting values between the IS and the control group.

The individual peak responses were much higher in the IS group and there was a significantly greater number of IS patients who reached a peak value of more than $30 \mu\text{g/l}$ ($P < 0.001$, binomial test). The mean peak values were $23.2 \pm 17.78 \mu\text{g/l}$ and $13.18 \pm 13.03 \mu\text{g/l}$ for the scoliotics and the controls, respectively, this difference is statistically significant ($P < 0.01$).

For the total sample of girls with IS the mean peak response time was 150 minutes after propanolol administration and 90

minutes after L-dopa (Figure 1). In the control group a marked peak in GH concentration occurred 60 minutes after administration of L-dopa but the rise was less pronounced. In addition, there was a second rise after the first peak, probably due to the emotional stress caused by the situation. No fall could be seen in the control group within the test period of 3 hours. The ICGH values for the IS group were significantly higher than for the controls during the time period 60-180 min ($P < 0.01$) as well as during the total test time ($P = 0.01$). When the 2 groups are considered, a significantly higher ICGH was found in the scoliotics for the

cal ages 7-12 years ($P=0.05$) Based on etal age, there was also a significantly er ICGH in the scoliosis patients in the igest age group, $P<0.005$ and $P<0.02$ the shortest and longest time period ectively (Figure 2) For girls over 12 s, no significant difference could be onstrated in ICGH levels compared er on the basis of chronological or skeletal (Figure 3 and Table 4) he mean peak response was significantly er in IS girls 7-12 years old when pared on the basis of skeletal age 0.02), but this was not so when they e compared on the basis of chronological

age ($0.05<P<0.1$) In girls older than 12 years (chr and skl.) no significant difference occurred in this respect (Tables 5, 6) In the boys, no significant difference between the IS and control groups could be demonstrated in ICGH values or in the values of mean peak response (Figure 4) There was however a significantly higher number of boys in the IS group, in whom the response exceeded the arbitrarily chosen threshold of $30 \mu\text{g/l}$ ($P<0.001$)

Testosterone and sex hormone binding globulin (SHBG) In girls, the serum level of testosterone was found to increase steadily from the age of 9 years (chr) to the age of 15

Table 4 Integrated concentration of GH (mean \pm s.d.) in the different age groups for scoliotics (IS) and controls (C)

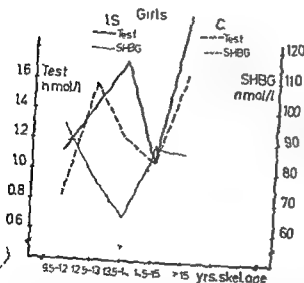
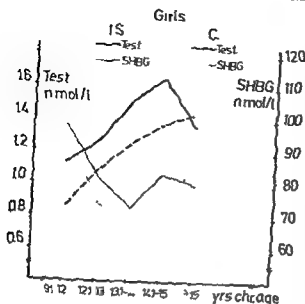
Age group	IS	ICGH (60-150 min) ($\mu\text{g min/l}$)		Signif test	
		n	n		
s < 12 yrs. chr	1240.0 \pm 612.6	12	780.6 \pm 630.1	16	P=0.05
s > 12 yrs. chr	1287.0 \pm 823.9	72	967.1 \pm 779.4	30	NS
s < 12 yrs. skl	1437.0 \pm 722.3	22	766.0 \pm 603.6	17	P<0.005
s > 12 yrs. skl	1225.0 \pm 816.5	62	982.0 \pm 792.9	29	NS
ls All ages	1280.0 \pm 794.2	111	902.2 \pm 729.3	46	P<0.01
s All ages	1596.0 \pm 929.4	11	1186.0 \pm 798.1	14	NS

Table 5 Mean serum levels of GH at different stages of the stimulation test in girls of both age groups

Time (minutes)	Mean (\pm s.d.) serum level GH ($\mu\text{g/l}$)			
	7-12 yrs. skl.		12.5-17 yrs. skl.	
	IS	C	IS	C
0 (propanolol)	5.8 \pm 6.3	5.5 \pm 6.5	7.3 \pm 9.1	4.3 \pm 5.5
1 (L-dopa)	6.2 \pm 7.4	3.9 \pm 4.3	9.4 \pm 8.5	7.5 \pm 7.4
2	8.5 \pm 6.1	5.7 \pm 6.2	7.9 \pm 8.5	7.7 \pm 8.7
3	23.3 \pm 14.6	12.4 \pm 13.1	17.1 \pm 15.4	13.6 \pm 13.1
4	25.9 \pm 20.1	10.7 \pm 8.1	21.8 \pm 17.0	15.3 \pm 13.9
5	17.8 \pm 13.8	15.2 \pm 10.3	17.4 \pm 13.3	16.2 \pm 14.0

Table 6 Mean serum levels of GH at different stages of the stimulation test in the total sample of girls and boys

Time (minutes)	Girls all ages		Boys all ages	
	IS	C	IS	C
0 (propanolol)	6.9 \pm 8.4	4.7 \pm 5.9	4.1 \pm 3.8	3.1 \pm 2.5
1 (L-dopa)	8.5 \pm 8.3	6.2 \pm 6.6	6.7 \pm 9.4	4.2 \pm 2.8
2	7.9 \pm 7.7	6.9 \pm 7.8	5.9 \pm 5.9	7.4 \pm 8.5
3	18.7 \pm 15.4	13.1 \pm 13.0	23.9 \pm 22.7	20.1 \pm 19.0
4	23.2 \pm 17.7	13.6 \pm 12.2	39.8 \pm 36.5	19.6 \pm 14.7
5	17.7 \pm 13.3	15.8 \pm 12.6	15.5 \pm 10.5	15.5 \pm 10.5



Figures 5-6 Mean levels of testosterone (test) and sex hormone binding globulin (SHBG) in scoliotics and controls (for s.d. values see Table 7)

Table 7 Blood levels of testosterone and sex hormone binding globulin (mean \pm s.d.) (nmol/l) at different ages in the scoliotic and control groups

Skel. age (years)	Testosterone (nmol/l)				SHBG (nmol/l)			
	IS	n	C	n	IS	n	C	n
9.5-12.0	1.12 \pm 0.43	15	0.82 \pm 0.30	11	94.9 \pm 31.3	17	87.4 \pm 44.1	11
12.5-13.0	1.43 \pm 0.62	11	1.58 \pm 0.74	6	77.4 \pm 26.9	17	90.2 \pm 21.1	11
13.5-14.0	1.73 \pm 0.91	15	1.23 \pm 0.44	8	64.6 \pm 23.3	20	53.9 \pm 17.5	11
14.5-15.0	1.07 \pm 0.22	11	1.07 \pm 0.24	7	87.4 \pm 30.1	15	11.5 \pm 1.7	11
>15.0	2.03 \pm 0.86	7	1.67 \pm 0.63	7	86.2 \pm 29.1	7	2.4 \pm 0.1	11

years and then a decrease in the oldest age group. This was the case in scoliotics and controls but the concentrations were markedly higher in the IS group at ages below 15 years, although the differences were not statistically significant (Fig. 5). The corresponding SHBG levels decreased from the youngest group towards the age of 15, and then a significant rise occurred in the oldest age group. The rise in SHBG concentration for the age group 14.1-15.0 (chr) among the scoliotics is not significant.

If the data are evaluated according to skeletal age, an increase in testosterone concentration could be observed from the age of 14, thereafter a decrease in concentrations occurred in the age group 14.5-15.0 years before a significant rise at the end of puberty ($P < 0.05$) (Figure 6 and Table 7). The mean serum level of testosterone in the youngest age group (9.5-12.0 yrs (skel)) was significantly higher in the scoliotic patients ($P < 0.05$) whereas the difference in SHBG values was small. With the exception of the age group 12.5-13.0 years (skel), SHBG concentrations decreased with increasing testosterone values and vice versa. The low concentration of SHBG in the oldest age group (skel) is surprising but the trend of the curve at this stage is not significant.

Oestradiol No significant differences could be demonstrated in oestradiol concentrations except for the age group over 15 years ($P < 0.05$), for the remaining age groups differences were negligible (Figure 8, Table 8).

Table 8 Blood levels of oestradiol (mean \pm s.d.) in girls of different ages in the scoliotic and control groups

Age (y)	Oestradiol (nmol/l)			
	IS	n	C	n
<12.0	0.11 \pm 0.07	15	0.12 \pm 0.07	11
12-13.0	0.33 \pm 0.33	10	0.35 \pm 0.32	5
13-14.0	0.23 \pm 0.10	15	0.25 \pm 0.13	8
14-15.0	0.37 \pm 0.21	10	0.31 \pm 0.24	7
>15.0	0.39 \pm 0.20	7	0.17 \pm 0.13	7

er hormones investigated No significant differences could be demonstrated between scoliotics and controls as far as the other hormones are concerned (Table 9). There, however, a marked lower blood concentration of prolactin in IS girls over 13 years ($0.05 < P < 0.1$), whereas no difference could be observed for the younger girls.

There was no correlation between the oestrone values and the severity of the deformity or between the GH values and scoliosis angle, nor could any correlation be demonstrated between the GH and testosterone values on the one hand and height or weight on the other.

DISCUSSION

In a longitudinal study of Swedish girls, Lilner (1974) found that the girls with IS

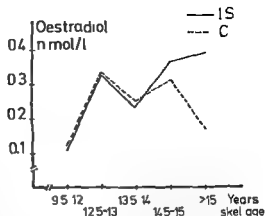


Figure 7 Mean levels of oestradiol in girls of different ages in scoliotics and controls (for s.d. values see Table 8)

had increased stature long before the onset of scoliosis. After the deformity had been diagnosed the difference in height between scoliotics and controls remained unchanged, but the rate of growth seemed to be equal in the two groups.

The present study seems to present sound evidence for differences in the hormonal status between scoliotics and controls which suggest that they have different growth patterns.

Frasier (1974) maintained that "there is general agreement that the measurement of GH in a single fasting blood sample is not an appropriate method of screening for growth

Table 9 Concentrations (mean \pm s.d.) of some growth related hormones in girls of different ages in the scoliotic and control groups. The units are in μ g/l except for thyroxine and cortisol which are in nmol/l

Hormone	Age group (years chr)	Blood concentration		Signif. test
		IS	C	
thyroxine	<13	103.0 \pm 16.8	111.3 \pm 20.8	NS
thyroxine	>13	103.5 \pm 23.8	105.2 \pm 18.7	NS
thyroxine	All ages	103.3 \pm 21.6	107.6 \pm 19.4	NS
prolactin	<13	14.22 \pm 7.51	14.48 \pm 7.97	NS
prolactin	>13	14.79 \pm 6.71	19.72 \pm 10.92	$0.1 > P > 0.05$
prolactin	All ages	14.57 \pm 6.97	17.48 \pm 9.95	NS
cortisol	<13	523.1 \pm 181.5	557.5 \pm 213.5	NS
cortisol	>13	455.4 \pm 152.9	414.2 \pm 128.8	NS
cortisol	All ages	480.2 \pm 165.7	479.9 \pm 183.8	NS
GH	All ages	0.907 \pm 0.41		
I	All ages	1.192 \pm 0.52		

hormone deficiency" It is of course not supposed to be more appropriate when looking for differences in "normal" pituitary function

The L-dopa stimulation test is a well established procedure for the evaluation of pituitary function (Eddy et al 1971, Chakmakjian et al 1973, Eddy et al 1974). However, as the response to L-dopa alone is inconstant and as propranolol, a beta-receptor blocking agent, has been shown to potentiate this response (Camanni et al 1974) it was decided to use the combined stimulation (Trygstad 1977). Fass et al (1979) found a markedly lower number of false positive results in the combined test compared to the L-dopa test and the sleep screen test. It has been shown that there is a significant correlation between standard pharmacological stimulation tests and the physiological 24-hour integrated serum concentration of growth hormone (Plotnik et al 1979).

The results of the stimulation test in this study indicate a significant, higher sensitivity of the GH release mechanism in prepubertal (7-12 years) girls with IS. The lack of a significant difference in age groups over 12 years corresponds well with the anthropometric data of Willner (1974) and Burwell & Dangerfield (1977). The present study also confirms the finding of Plotnik et al (1974), that the ICGH is the same in prepubertal and pubertal normal girls. Girls with IS, however, have higher ICGH before puberty.

Testosterone is an important growth factor during adolescence in girls as well as in boys (Wilkins 1965), and is probably, in addition to the adrenal androgens, responsible for the prepubertal growth spurt even in girls (Sizonenko 1978).

Hence, the present finding, demonstrating a significantly higher concentration of testosterone in serum of the IS girls aged 9-12 years (skel) may be of pathogenetic importance.

Since only free testosterone is supposed to be biologically active (Vermeulen et al 1969), the inverse relationship between SHBG and testosterone indicates a potentiation of its

growth promoting action. The late and the pubertal peak in testosterone concentration in the IS group suggests a pre-growth spurt in these children (Figure 1).

The difference in oestradiol values at age of 15 years is not easy to explain; however, it is reasonable to think the drop in oestradiol in the controls is a fluctuation.

An attempt has been made in this study to reduce the sources of errors by using two populations which are to be as homogeneous as possible. The test conditions have been exactly the same for both groups. Emotional stress as well as physical exertion known to influence GH secretion were excluded. All children involved were admitted to hospital but none of them were waiting for surgical intervention. In spite of the fact that the patients were calmed down before the test started, some of them became restless and this may be the reason why a lower rise in GH concentration occurred in the control group. A secondary elevation of GH concentration did not occur in the control group, probably because the maximal rise is followed by a refractory phase. There is good documentation for the fact that the maximum response normally occurs 60-90 minutes after L-dopa administration (Eddy et al 1974, Camanni et al 1974).

The great variance of the individual responses in a study of this kind makes statistical analysis difficult, nonetheless, the difference could be clearly demonstrated. There seems to be little doubt about the higher testosterone levels in prepubertal scoliosis girls or the increased rise in growth hormone in the same group. The difference in growth rate is especially marked during these years and it is in this age group that most of the IS cases are diagnosed.

In boys, no significant differences were found in testosterone concentration. However, even if the group was too small to permit division into age groups, the trend similar to that found in the girls may be shown in the GH release test.

Nordwall & Willner (1975) found that

IS had an earlier skeletal development controls in the age group 11–12 years.

In the present study it was therefore interesting to find that hormonal differences are even more marked when comparing populations on the basis of skeletal age. The choice of 12 years of age as the start of puberty might be a matter for discussion. The normal development of secondary sexual characteristics starts earlier and the growth certainly starts earlier. However, the skeletal age is more difficult to determine reliably before the age of 12 years and it is also convenient to choose this age in order to avoid statistical problems with small sizes.

The lack of correlation between hormones on the one hand and anthropometric sizes and severity of scoliosis on the other was not unexpected. A more detailed report on the anthropometric measurements done in connection with this study will be published.

The present findings are consistent with those of Willner (1974) and Burwell & Dangerfield (1977) who found differences in final height between scoliotics and controls. Though Burwell et al. could not demonstrate significant differences, they did correct for loss in height caused by the deformity. Willner (1972) also found that the final height was greater in girls with IS and the "young girls" (11–13 years) even without acting for the deformity.

The question as to whether the primary cause of scoliosis is due to a different growth pattern has not been addressed in this study. Nevertheless, hormones may influence the growth in a way which could be relevant to scoliosis. Dymling & Willner (1978) reported a case in which a marked progression of the scoliosis occurred during treatment with GH and testosterone.

It is possible that the growth hormone treatment might have a direct effect on the growth plate, but this is not clear.

It is known that growth hormone treatment tends to decrease the mechanical stability of the epiphyseal plate (Oka et al. 1978). On the other hand when it is given in larger doses

the growth plate becomes narrowed and after some time will fuse. Thus, if hormones can affect both spinal geometry and material properties, the possible role of growth-regulating hormones as primary factors in the development of idiopathic scoliosis should not be totally excluded.

CONCLUSION

The blood levels of growth promoting hormones in children with idiopathic scoliosis were significantly higher than in a control group. The higher sensitivity of the pituitary release mechanism of growth hormone and the elevated concentrations of testosterone could be the reason for the accelerated prepubertal growth reported in these children.

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AUTO-TRACTION FOR TREATMENT OF LUMBAGO-SCIATICA

Multicentre Controlled Investigation

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In this controlled prospective study of the Auto-traction method for the treatment of lumbago-sciatica, 82 patients were randomly allocated to either treatment with Auto-traction for up to three 1-hour sessions in 1 week, or they were given a corset and advised to rest. The orthopaedic surgeons participating in the study worked at six different hospitals and all had limited experience of the Auto-traction method obtained during a 1-week course. All patients were clinically evaluated by an independent observer who also performed the follow-up examinations 1 and 3 weeks after the treatment sessions. In addition a 3-month follow-up was performed by letter.

The Auto-traction method gave prompt relief of pain and a normalizing of the SLR test more often than treatment with only a corset and rest. The difference between the two treatment groups was statistically significant. The immediate difference noted between the treatment groups had decreased slightly at 3 weeks but was still statistically significant at this time.

Key words: back pain, sciatica, therapy, traction.

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Surgical treatment of lumbago and sciatica offers a wide range of alternatives, including manual physiotherapy, manipulation and other manual methods, and traction. The abundance of methods and the uncertainty as to which of them are the most satisfactory is understandable in view of the fact that the underlying cause of the pain is in most cases unknown (Nachemson 1971). Although the different methods of treatment have been extensively used for many years, few systematic studies of their efficacy have been carried out. In most cases, back disorders are episodic and regress spontaneously (Hult 1955, Horal

1969). Controlled studies are therefore generally necessary to determine whether the treatment is more effective than no treatment at all, or whether a particular method of treatment is better than other methods.

Dynamic physiotherapy has been found in several studies to give poor results compared with other methods of treatment (White 1966, Kendall & Jenkins 1968, Lidström & Zachrisson 1970). There are thus indications that this type of treatment is ineffective and may even aggravate the symptoms.

Various manual treatments have been studied in a number of controlled trials in

patients with lumbar symptoms (Glover et al. 1974, Doran & Newell 1975, Rasmussen 1977, Brodin 1977, Bergquist-Ullman & Larsson 1977). The results of these studies are contradictory. They do suggest, however, that treatment of lumbago patients with manipulation or other manual methods may accelerate recovery in some patients. In the long-term, however, the treatment does not seem to offer any advantages. One of the studies shows that equally good results can be obtained by giving patients information and ergonomic advice, "the Back School" (Bergquist-Ullman & Larsson 1977). In two controlled studies in patients with lumbago-sciatica and disc herniation, conventional traction (Tru Trac) was not found to be superior to placebo treatment (Lidström & Zachrisson 1970, Weber 1973).

These studies have either shown poor results of treatment or positive effects that were of limited or marginal significance in most cases. The results reported by Lind (1974) with her own method, Auto-traction, developed from previous methods of traction, stand out in sharp contrast to these disappointing results with other methods. Lind (1974) presented her results with the method in three different studies. In a controlled trial in patients with lumbago-sciatica all 15 traction patients were rid of their pain within 1 week, whereas only a few of the patients in two equally large control groups were free from pain. In an uncontrolled study 20 patients with disc herniation confirmed by myelography were treated with Auto-traction before planned operation. Fifteen of the patients recovered so permanently that they did not need surgery. In a retrospective study of the results in a large number of patients with lumbago or lumbago-sciatica, more than 90 per cent of the patients are reported to have become free from pain after the treatment (Lind 1974). In addition to pain relief, regression of the neurological deficit symptoms was achieved in many of the patients. Rapid recovery from back symptoms in such a high proportion of patients has seldom been reported previously

in the medical literature. An exception: very good results initially reported after denervation, but in later studies they were less impressive (Rees 1971, Sjöström & Lora & Long 1976, King 1977). The results reported by Lind (1974) are superior to what can be expected after open-verified disc herniation (Hirsch & Vahl 1963, Hakelius 1970, Spangfort 1977).

The aim of the present study was to determine whether the results reported by Lind (1974) could be reproduced. The primary objective was to find out if the results could be obtained when the method was used by relatively untrained patients and not by the inventor. A secondary objective was to consider most suitable for purpose.

PATIENTS AND METHOD

Auto-traction

The treatment is performed on a special bench. The bench is made up of two parts which can be individually angulated and rotated. 1) The patient is positioned on the bench in prone, supine or lateral position. The patient's pelvis is fixed to the foot end of the bench with a belt and a chain. The patient's head is fixed to the head end of the bench by the bars at the head end and supports his feet on the bars at the foot end. Traction is performed by the patient himself by pulling on the bars at the head end with his arms, and he is constantly in control of the traction. The direction of the traction can be changed by changing the angulation of the bench, the patient's position, and the position of the traction-belt. Treatment is most often performed in a horizontal position. The position and direction of traction are changed as the treatment proceeds. The results are found when the symptoms disappear or are normalized during traction. It is often predicted that this position by analyzing the clinical condition and symptoms at the beginning of the treatment session, that can last for up to 1 h. After the treatment the patient is supplied with a high fabric corset and a special pillow for the waist to achieve lumbar lordosis in the position. Repeated treatment sessions are required. The patient is confined to bed for a few days after the treatment and the traction is gradually increased in the corset. The treatment



Figure 1 The multiplane Auto-traction table



Figure 2 The Auto-traction table with a patient in the supine and lateral positions

onomic advice and equalization of leg length differences. A more detailed description of the exact method of treatment and aftercare is to be found in our work (1974).

Study

The study was designed as a randomized controlled trial in a defined group of patients. The patients were treated at six departments of orthopaedic surgery (the Department of Orthopaedic Surgery at Malmö Skövde, Örebro and Västra Hospitals and at Sahlgrenska Hospital in Göteborg and at Karolinska Hospital Stockholm) by five orthopaedic surgeons who

had attended a 1-week course of instruction by G. Lund 1 year earlier and had subsequently gained some personal experience of the method. A few patients were also treated by G. Lund herself. The patients were examined by an independent investigator who visited the different units regularly.

- a. Neurological deficit.
- b. Duration of the current episode ≥ 2 weeks and $\leq 3 \frac{1}{2}$ months.
- c. Age 20–55 years.
- d. Positive Straight Leg Raising test (SLR).

groups

Patients allocated to the *Auto-traction group* were given up to three treatments all within 1 week. The treatment sessions were not to last for more than 1 hour. Patients treated as outpatients were usually taken home by ambulance. The control group were fitted with a corset of the same type as the traction group and given the same instructions with respect to rest. Standard analgesics (paracetamol) were prescribed when required for both groups. The patients were treated as outpatients except at one hospital where all patients (10 traction patients and 10 control patients) were hospitalized for 5 days.

Data were registered on a standardized protocol immediately before and 1 and 3 weeks after the start of treatment.

At the first investigation, before the start of treatment, previous back symptoms and the duration of the present episode of pain were recorded. The nature, extent and intensity of the pain were determined. The intensity of the pain in the leg and back was graded on a 0-100 scale

using a graphic self-rating method (1974). The patient's clinical condition, SLR, lumbar mobility and the condition in the lower extremities. The range of lumbar mobility was using a method by which certain parts of the lumbar spine are measured (Näslund 1971).

At the investigations after 1 and 3 weeks patient was asked whether he still had pain in leg or back. If so the pain was asked the same way as at the first investigation. Likewise the clinical signs were noted. Additional treatment was given between investigations at 1 and 3 weeks. In order to elucidate the long term course the present a self administered questionnaire after about 3 months.

For the statistical analysis χ^2 test and exact test were used.

RESULTS

Two patients allocated in Auto-traction were excluded at an early stage. One of the

Table 1 Clinical details of the two groups of patients before the onset of treatment. Percentages in parentheses. N = number of patients. SLR = Straight Leg Raising test.

Clinical data	All patients		Patients given Auto-traction	
	Auto-traction N = 41	Corset N = 41	Positive effect of treatment N = 17	No positive effect of treatment N = 24
ANAMNESTIC DATA				
Mean age (years)	36.5	38	35	37
No. of female patients	12	19	4 (24)	8 (33)
No. of patients with earlier episodes	33	27	13 (76)	20 (83)
Mean duration of recent episode (weeks)	6.5	6.8	6.4	6.6
No. of patients on sick leave	37	38	15 (88)	22 (92)
THE CLINICAL PICTURE				
No. of patients with radiation of pain below the knee	36	37	14 (82)	22 (92)
No. of patients with decreased reflexes or paresis	20	25	7 (41)	13 (54)
No. of patients with disturbance of sensibility	11	23	3 (18)	11 (46)
Mean value of SLR test	42°	38°	43°	42°
No. of patients with bilateral positive SLR test	18	20	5 (29)	13 (54)
No. of patients with crossed SLR test	3	3	0	3

receive treatment and the other was unable to perform the traction. The study thus included 82 patients, with 41 in each treatment group, and comprises all patients fulfilling the criteria who could be collected during the 3-month period of the trial. All patients were observed for 3 weeks and 81 could be contacted for follow-up after about 3 months. On average, the patients in the Auto-traction group received 2.5 treatments.

Clinical details

The clinical details of the patients before start of treatment are given in Table 1. About half the patients in each group showed absence of the Achilles reflex, of reduced strength on dorsal extension of the foot or so. The corset group contained more men and more patients with reduced mobility. The other clinical features listed in Table 1 were evenly distributed between the two groups.

Number of recoveries within 3 weeks

Expression of pain in the leg and back. Table 2 shows the number of patients who were free from pain at the follow-up examinations

after 1 and 3 weeks. Patients who became free from pain in both back and leg and those in whom only the back pain or only the sciatica was relieved are shown separately. Fifteen per cent of the traction patients recovered fully within 1 week, compared with none of the corset patients. Freedom from pain in their back or leg at 1 week stated during the same period in a further 27 per cent of the traction patients and in 4 per cent of the corset patients. As shown in Table 3, the differences between the treatment groups were statistically significant for both complete and partial recovery after 1 week. Twelve of the 17 traction patients who were free from pain in their back or leg at 1 week stated that they had recovered immediately after the treatment, while the remaining 5 patients were unable to state any direct temporal relationship. Between 1 and 3 weeks the differences between the treatment groups decreased somewhat. Four of the traction patients who had experienced complete or partial recovery at 1 week had suffered recurrence of pain in the back or leg at 3 weeks and a few more patients in each group had recovered. At the 3-week follow-up there was no longer a significant difference between the number of fully recovered patients in the

Table 2 Number of completely and partly recovered patients after 1 week and 3 weeks. Group 1 Free from pain both in the back and in the leg. Group 2a Free from pain in the leg but not in the back. Group 2b Free from pain in the back, but not in the leg. Group 3 Pain in the back and in the leg. Percentages are given in parentheses.

	1 week		3 weeks	
	Auto-traction	Corset	Auto-traction	Corset
completely recovered				
Group 1	6 (15)	0 (0)	7 (17)	3 (7)
partly recovered				
Group 2a	8 (20)	1 (2)	9 (22)	4 (10)
Group 2b	3 (7)	1 (2)	4 (10)	1 (2)
not recovered				
Group 3	24 (58)	39 (96)	21 (51)	33 (81)
Total	41 (100)	41 (100)	41 (100)	41 (100)

Table 3 Statistical analysis of differences in results between the two treatment groups

	1 week	3 weeks
Completely recovered	$P < 0.05$	Not significant
Completely recovered or free from pain in the leg	$P < 0.001$	$P < 0.05$
Completely recovered or free from pain in the leg or the back	$P < 0.001$	$P < 0.01$

two treatment groups. However, if the patients who had achieved relief from pain in either the leg or back also are included, the difference between the two groups was still statistically significant ($P < 0.01$). At the 3-week follow-up 15 of the traction patients and 5 of the corset patients had a negative SLR test. This difference is also statistically significant ($P < 0.01$). In all patients except two the sciatica had disappeared when the SLR test was negative.

Regression of the SLR test Before treatment all patients had a positive SLR test. At the first follow-up 11 of the traction patients had a negative SLR test, compared with none of the corset patients. This difference is statistically significant ($P < 0.01$). At the 3-week follow-up 15 of the traction patients and 5 of the corset patients had a negative SLR test. This difference is also statistically significant ($P < 0.01$). In all patients except two the sciatica had disappeared when the SLR test was negative.

Regression of the neurological abnormalities In the Auto-traction group, the Achilles reflex returned in one patient and two patients reported regression of reduced sensibility within 3 weeks of the start of treatment.

These three patients belonged to the group that did not experience regression of pain after treatment. In the remaining Auto-traction patients the neurological deficit persisted after 3 weeks.

Relief of pain in patients who had recovered

About half of the patients with persistent symptoms after 1 week in both treatment groups experienced alleviation of the pain. Several methods were used to compare the degree of improvement in patients with persistent symptoms. However, no statistically significant difference could be detected between the two groups with respect to the degree of alleviation of pain in patients with some persistent pain in the back or the leg.

Results after 3 months

Table 4 shows the number of patients with persistent symptoms more than 3 months after entry into the study. There was no significant difference between the two groups with respect to the number of persistent symptoms had either been associated with

Table 4 The number of patients with symptoms persisting for more than 3 months after entry into the study

	No	Auto-traction ¹ n	No	Corset n
Persisting symptoms	21	53	24	41
Free from symptoms	19	47	17	41
Total	40	100	41	100

¹ Data lacking for one patient.

urred after disappearing for from 1 to 4
eks. The number of patients who had
covered completely and subsequently ex-
perienced a recurrence of the symptoms
during the period of observation was
atively small (5 patients in the traction
up). Most of the patients in Table 4 with
sistent symptoms had thus had symptoms
throughout the period of observation. We
ve no information regarding the intensity
s extent of symptoms at 3 months.
Alternative methods of treatment were often
ed after the first 3 weeks. Four traction
ients and six corset patients had
dergone operations for disc herniation at
time of the follow-up.

DISCUSSION

There were clear differences between the two
groups with respect to the results of the
treatment. Complete freedom from pain or
freedom from pain in either the back or legs
was achieved rapidly in 42 per cent of the
Auto-traction patients, compared with only 4
per cent of the corset patients. Only 15 per
cent of the Auto-traction patients became
completely free from pain, however. The
results are thus clearly less favourable than
previously reported (Lind 1974), in spite of
the fact that the series seem comparable. The
therapists in this study, however, had limited
experience of the method and at the most three
treatment sessions were given in 1 week, each
lasting for only 1 hour. No conclusions can be
drawn from this study as to what results
might be achieved if these conditions were
altered. In the more successful series of Lind
(1974) multiple, prolonged treatment sessions
were often used.

It appears that the patients who did not
become free from pain in the leg or back, also
did not achieve any lasting alleviation of the
pain.

In contrast to the findings of Lind (1974)
neurological symptoms were not
influenced by the treatment. The neurological

deficit symptoms of disc herniation usually
persist, however, for a long time after both
surgical and conservative treatment (Weber
1978).

It is always difficult to judge whether a
certain effect of treatment is the result of a
direct influence on the cause of the pain or
merely a placebo effect. The Auto-traction
method is probably associated with a greater
placebo effect than treatment with only a
corset and rest. On the other hand, there are
certain factors which may be regarded as
circumstantial evidence that the difference
between the two groups was not merely due
to a placebo effect. The effect of treatment
generally appeared in immediate association
with the traction and was often accompanied
by a negative SLR test. There was a
tendency for poorer results in patients with
bilateral positive or crossed SLR test or
reduced sensibility. This may be taken as
demonstrating that mechanisms other than
pure psychological factors determined
whether or not the patient would respond to
the treatment.

A corset and rest were included in both
treatment groups, in an endeavour to restrict
the difference in management of the two
groups to the Auto-traction. It is possible
that the patients in the Auto-traction group
complied better with the directions regarding
bed-rest during the week of treatment. The
difference in results between the two groups
can hardly be explained by this factor,
however. At one of the hospitals all patients
in both groups were hospitalized and confined
to bed for 5 days. In spite of the fact that
complete rest was thus guaranteed, this
hospital reported the greatest difference in
results between the two treatment groups.
The surgeon at this hospital also had the
most experience with Auto-traction.

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TOTAL HIP REPLACEMENT IN CONGENITAL DISLOCATION OF THE HIP

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Twenty cases of congenital dislocation of the hip were treated with total hip replacement. The hips were completely dislocated with the femoral head supported by a nearthrosis proximal to the original acetabulum. The concept was to reconstruct the hip with an acetabular cup at the site of the original acetabulum even if a portion of the proximal end of the femur had to be sacrificed in the process. The Harris prosthesis appears, in most instances, to be the most suitable type of prosthesis but it was concluded that the surgeon needs a selection of prostheses for this procedure. Nine-tenths of the patients were improved by the procedure and the complications could mostly be successfully dealt with. This type of surgery is justified in cases with special indications.

Key words: congenital dislocation, hip endoprosthesis.

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The first report of the surgical management of congenital dislocation of the hip (CDH) was presented by Schantz (1922). The method used – the osteotomy – was later modified by Hass (1943) and by Blount (1952). Also in 1952, Merle d'Aubigné presented a series of 16 hips with CDH treated by the procedure of Smith-Petersen (1951). Smiley & Feagin (1973) after the introduction of total hip replacement (THR) at first used against the use of this method in CDH because of the technical difficulties. However, Harris (1974) and Harris et al (1977) have demonstrated, using a modified THR operation designed by Harris himself, that THR operations can be successful also in completely dislocated hips. Data supporting this view have been presented by Dunn & Wallace (1976), Hess & Umber (1978) and Rowe et al (1979).

PATIENTS AND METHODS

Twenty hips in 16 patients, all women, were included in the study. The criterion for selection was a complete dislocation with the femoral head articulating in a nearthrosis proximal to the original acetabulum. The criterion for operation was primarily pain rather than limping and limitation of motion. Pain at rest was not a major problem in these patients and has not been evaluated. The average age of the patients was 50 years (range 19–69) and the time of follow-up 18 months (range 6–36). The duration of pain prior to the operation was 5–20 years. In seven cases previous operations had been carried out in the same hip (intertrochanteric osteotomy in four, the procedure of Smith-Petersen in three and a subtrochanteric rotational osteotomy together with the Charni procedure in one case). Although, only four cases were operated on bilaterally all but four patients had bilateral CDH with varying degrees of deformity and symptoms from the contralateral hip. In several cases there were also deformities of

the spine the knee or the other hip. In one patient the CDH was associated with arthrogryposis.

Surgical procedure

The concept of Harris (1974) that the acetabular cup should be implanted at the site of the original acetabulum was applied in all cases.

Osteotomy of the trochanter and the femoral head were performed and the capsule completely excised. The position of the sciatic nerve was determined. The iliopsoas tendon often had to be released from the lesser trochanter and sometimes also the rectus muscle from the lower anterior iliac spine. After the dissection it was possible to pull the femur distally. Hooks were applied at the pecten ossis pubis, the obturator and the ischiadic foramina as guides for the localization and reaming of the original acetabulum. In 11 hips the acetabular roof was reinforced by transplantation of the femoral head fixed with screws. The femoral shaft was then shortened to a convenient length in order to permit the insertion of the femoral stem. The following prostheses were used. The Harris type in nine hips, the LeGrange le Tournel in five hips, the Christiansen in five hips and the Lubinus in one hip. After the insertion of the two components of the prosthesis the trochanter was in 10 hips, attached to the femur by wires.

Antibiotic prophylaxis with Cloxacillin for 7 days was used in all patients. In two cases Gentamicin was added to the methylmethacrylate cement. The perioperative bleeding was 2100 ml (range 1000-4800) and the duration of the operation was 131 minutes (range 52-185).

Complications

Peroperative Seventeen of the operations were uncomplicated. In two cases the femoral shaft was fractured: in one case there was perforation of the shaft by the femoral stem and in one a fracture of the trochanter.

Postoperative Four hips dislocated post operatively.

Primary dislocation occurred in two hips both were treated with open reduction and there was no re-dislocation.

Secondary dislocation occurred in two hips. One patient had three dislocations within 2 months and was treated with closed reduction under general anesthesia without further re-dislocation. Another patient had multiple dislocations treated with open and closed reductions. The prosthesis was in this case exchanged twice. After the most recent exchange to a Charnley prosthesis with a



Figure 1 Preoperative X-ray of a femoral head and neck.

long neck this patient has had two more years of dislocation separated by long intervals. No neurovascular injuries were encountered. No clinical signs of thromboembolic complications or infection.

RESULTS

Out of the twenty hips evaluated radiologically free from symptoms, ten remained unchanged and one worse (the one with multiple dislocations). All patients had operative walking pain which disappeared in 14 out of 20 hips evaluated. Walking speed and function are briefly presented in Table 1. Inability to balance the pelvis - the Trendelenburg sign - was not preoperatively evaluated and the results are therefore inconclusive (Table 2).

DISCUSSION

The THR procedure in CDH is a difficult operation with the present

Table 1 Walking distance and function (16 patients)

		Preoperatively	Postoperatively
walking distance without pain	0-1000 m	16/16	9/16
"	1000-3000 m	0	2/16
"	> 3000 m	0	5/16
walking without support		5/16	10/16
able to climb stairs		4/16	0/16
noticeable leg length difference		16/16	9/16



Figure 2 Postoperative X-ray. A Harris prosthesis has been inserted and the acetabular roof reinforced with a transplant of the femoral head.

Table 2 The Trendelenburg sign before and after THR in CDH (12 and 20 patients respectively)

	Preoperatively	Postoperatively
Positive	10/12	13/20
Negative	0/12	3/20
Uncertain	2/12	4/20

However, when the femur is hypoplastic with a narrow cavity the Harris mini or micro-mini type is the only possibility. Firm fixation of the trochanter is important in order to avoid postoperative dislocation and lumping, particularly when the gluteal muscles are atrophic as in our patient with multiple dislocations. This patient had been operated on three times before the THR.

With early detection and treatment of CDH there will be less need for this type of surgery. Since the cases are few it is impossible for the average orthopedic surgeon to gain the experience necessary for successful surgery of completely dislocated CDH. In this study there was improvement in 9/10 of the patients, a success rate similar to those presented in the previous studies. The complications, mostly dislocations of the prosthesis, can be successfully dealt with. The procedure is therefore justified in the hands of a few and in patients severely disabled by their condition.

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...se for new problems to arise. The anatomy is confusing, in particular the identification of the original acetabulum. Even if the Harris prosthesis is superior in cases with a short femur and a completely excised trochanter it is necessary to have a choice of other types.

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CLASSIFICATION OF TROCHANTERIC FRACTURES

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A comparative analysis of the information contained in five different classification systems was performed

The system classifying the fractures into five types in relation to the comminution of the calcar femorale or greater trochanter was found to be superior to the others as it contained the most reliable information about the possibility of obtaining stable fracture reduction and gave the most accurate prediction of the risk of secondary fracture dislocation

Key words: femoral neck fractures, fractures, classification

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A comparison of the results obtained with different methods of internal fixation in trochanteric fractures it is essential to take into consideration how the fractures have been assessed, as misleading conclusions might otherwise be drawn

Numerous follow-up studies have not classified the fractures at all (Cleveland et al 1959, Kennedy et al 1957, Petersen et al 1974, Sahlstrand 1974, Sarmiento 1963, Taylor et al 1944, 1955), whereas some series have divided the fractures into displaced and undisplaced (Hafner 1951, Rasmussen 1953, Wade et al 1959). Another system was based on the fracture mechanism (Ender 1970, Gardner & Simon-Weidner 1970). As many as 12 systems have been developed in which the fractures are assessed as stable or unstable in an attempt to describe the mechanical fixation problems involved in connection with internal fixation procedures.

The first demand on a classification system is that it should contain valid information concerning the possibility of obtaining a primary stable and anatomical fracture reduction. The second demand is a prediction of the risk of secondary fracture dislocation following internal fixation.

From these premises an evaluation and comparison of the existing classification systems was undertaken with the purpose of selecting the system which most accurately predicted the prognosis of the fracture treatment.

PATIENTS AND METHODS

During the period January 1st 1978 to June 30th 1979, 234 patients with trochanteric fractures were treated with the sliding screw-plate internal fixation system (Clawson 1964, Jensen et al 1978). With this type of internal fixation technical failure as well as secondary impaction of the fractures following telescoping of the screw are encountered. Both situations lead to bony support between the fracture surfaces.

The fractures were assessed from the preoperative X-rays using the five classification systems described in Table 1. The Evans classification system (1949) as slightly modified by Jensen & Michaelsen (1975) is illustrated in Figure 1.

The fracture reduction was evaluated from the immediate postoperative X-rays. Anatomical reduction was defined as a maximum diastasis over the fracture line of 4 mm. Fracture diastasis exceeding the 4 mm was looked for medially and laterally in the AP projection and anteriorly or posteriorly in the lateral projection.

Table 1 Classification systems for trochanteric fractures

Primary Dislocation

Type 1 undisplaced

Type 2 displaced

Presence of Medial Comminution

Type 1 stable, i.e. no medial comminution

Type 2 unstable, i.e. dislocated lesser trochanter or larger femoral arch fragment

Ender's System (1970)

Type 1 eversion fracture, i.e. posteromedial rotational wedge

Type 2 impaction fracture, i.e. inversion and adduction of neck fragment with varus deformity

Type 3 diatrochanteric fracture, i.e. fracture line extending subtrochanterically or being trans-

Tronzo's System (1973)

Type 1 incomplete fracture only involving greater trochanter

Type 2 uncomminuted fracture, with or without slight displacement. Intact posterior wall with relatively small lesser trochanter fragment

Type 3 comminuted posterior wall with telescoping of neck spike into shaft fragment. Lesser trochanter fragment large

Type 4 like Type 3, but greater trochanter totally broken off

Type 5 comminuted posterior wall without telescoping of the two major fragments. Lesser trochanter displaced outside shaft. Most posterior wall lost medially

Type 6 reversed oblique fracture with medial displacement of shaft. Greater trochanter or lesser trochanter to neck fragment

Evans' System (1949)

Type 1 undisplaced 2-fragmentary fracture

Type 2 displaced 2-fragmentary fracture

Type 3 3-fragmentary fracture without posterolateral support due to dislocated greater trochanter fragment

Type 4 3-fragmentary fracture without medial support due to dislocated lesser trochanter or femoral arch fragment

Type 5 4-fragmentary fracture without medial and posterolateral support. Combination of Types 3 and 4

The fractures were X-rayed regularly until fracture union or technical failure of fixation was experienced. The occurrence of technical failure as well as telescoping of the implant with secondary impaction were registered. Technical failure was defined as bending or loosening of the implant and cutting or penetration of the screw through the bone. Secondary dislocation was defined as impaction or varus displacement due to technical failures or impaction due to telescoping of the implant.

Statistical analysis of the data was applied. An information analysis was performed by multi-dimensional contingency tables adding variables in steps and comparing in relation to Kullback's information measure (1959). For each step of the analysis the significance of the information contained was calculated. In addition a multiple contingency table analysis was performed with successive testing as described by Madsen (1976).

RESULTS

A review of the different classification systems is presented in Table 2. The results are based on the preoperative X-ray and the quality of fracture reduction and the immediate postoperative X-ray.

Applying a step-wise information analysis to the Evans classification system will contain the most reliable information ($P < 0.00005$) about the possibility of achieving anatomical reduction of different fracture types. Having established the Evans system the next step of the analysis revealed that the second best system was considering only the primary displacement of the fracture ($P < 0.00005$). The results

STABLE



UNSTABLE



fragmentary fract
without medial support

4 fragmentary fract

Figure 1 Classification of trochanteric fractures according to Evans (1949) as modified by Jensen and Suckaleisen (1975)

Results did not give any significant information in the subsequent steps of the analysis (0.3539).

It appears from Table 2 that the stable 2-fragmentary fractures (Types 1 and 2 according to Evans) can be anatomically reduced in both planes in 94 per cent (32/34) of cases. The remaining three fracture types of the Evans system are all considered unstable. Of the fractures with detachment of the greater trochanter fragment (Type 3) only 10 per cent (31/95) could be anatomically

reduced in both planes. The instability of this fracture type is caused mainly by the difficulty of obtaining reduction in the lateral plane, which was the case in 64 per cent (61/95). In 28 per cent (27/95) this was combined with a medial diastasis. Among fractures with detachment from the calcar femorale (Type 4) only 21 per cent (6/28) could be anatomically reduced in both planes. The main problem is the postoperative medial diastasis encountered in 64 per cent (18/28) of cases. Type 5 fractures with detachment of both trochanters could be anatomically reduced in only 8 per cent (6/77) of cases, whereas fracture diastasis was encountered in 69 per cent (53/77) in both planes.

Table 3 compares the preoperative classification according to the different systems with the secondary fracture dislocation, as evaluated from the final X-rays. The step-wise information analysis was repeated and confirmed that the Evans classification system was significantly the most informative also in this respect ($P < 0.018$). In the second step of the analysis the second best system was again that based on the primary fracture dislocation ($P < 0.00005$). No additional information was contained in the remaining systems ($P < 0.1335$) according to the subsequent steps of the analysis.

Stable 2-fragmentary fractures (Types 1 and 2 in the Evans system) were followed by secondary dislocation in 9 per cent (3/34) of cases, whilst Type 3 fractures dislocated in 58 per cent (55/95), mainly due to fracture diastasis in the lateral plane or bi-plane diastasis. Lack of medial support (Type 4) led to secondary dislocation in 61 per cent (17/28) of cases. This was caused by medial or bi-plane diastasis in 33 per cent (15/17). Secondary dislocation occurred eventually in 78 per cent (60/77) of the highly comminuted 4-fragmentary fractures (Type 5). In 80 per cent (48/60) of cases these dislocations were caused by fracture diastasis in both planes.

The Evans classification system thus revealed a grading which included a decreasing possibility of anatomical reduction and an

Table 2 Classification of trochanteric fractures in relation to the quality of reduction

Type	Number	Anatomical reduction in both planes	Fracture diastasis in lateral plane	Fracture diastasis in AP plane	Fracture displacement
<i>Primary Dislocation</i>					
1	41 (18%)	30 (73%)	7	4	0
2	193 (82%)	45 (23%)	43	18	14
<i>Medial Comminution</i>					
1	139 (59%)	63 (45%)	39	6	31
2	95 (41%)	12 (13%)	11	16	11
<i>Ender system</i>					
1	114 (49%)	49 (43%)	18	13	31
2	106 (45%)	23 (22%)	31	6	41
3	14 (6%)	3 (21%)	1	3	15
<i>Tronzo system</i>					
1	2	1	1	0	0
2	106 (45%)	59 (56%)	23	10	14
3	33 (14%)	4 (12%)	4	4	2
4	52 (22%)	6 (12%)	18	5	25
5	40 (17%)	5 (13%)	4	3	23
6	1	0	0	0	1
<i>Evans' system</i>					
1	25 (11%)	24 (96%)	1	0	0
2	9 (4%)	8 (89%)	1	0	0
3	95 (41%)	31 (33%)	34	3	27
4	28 (12%)	6 (21%)	4	13	12
5	77 (33%)	6 (8%)	10	8	41

increasing risk of secondary dislocation ($P < 0.01$, Spearman-test)

A multiple contingency table analysis was applied and revealed that the fracture types according to Evans determined the quality of reduction ($P < 0.00005$). The comminuted fractures were thus more difficult to reduce. In the continuation of the analysis it appeared that secondary dislocation was determined by the quality of the reduction ($P < 0.00005$). This meant that secondary dislocation depended solely on the quality of reduction and not on the fracture type as such.

DISCUSSION

The simplest possible method of classifying trochanteric fractures is to divide them into displaced and undisplaced (Hafner 1951,

Rasmussen 1953, Wade et al. 1977) leads to fairly reliable information on the fracture reduction and the risk of secondary dislocation. More than 50 per cent of fractures will be in the risk group 1b and consequently the system does not have sufficient grading.

Ender (1970) described a system for the fracture mechanism in connection with his own method of internal fixation with condylocephalic nails (Ender 1972, F. Simon-Weidner 1970, Kroll & Poigenfürst & Schnabl 1977). In the present analysis this system does not give any reliable prediction of the risk of secondary dislocation or secondary fracture. It does not differentiate sufficiently.

The mechanical importance of the femoral head has been pointed out in several reports, leading to a classification of

Table 3 Classification of trochanteric fractures in relation to secondary fracture dislocation

Secondary Dislocation in Relation to Reduction						
Anatomical reduction both planes	Diastasis lateral plane	Diastasis AP plane	Diastasis both planes	Telescoping	Technical failure	Secondary dislocation total
<i>Dislocation</i>						
1 (3%)	5 (71%)	4 (100%)	0	9	1	10 (24%)
5 (11%)	27 (63%)	12 (67%)	81 (93%)	118	13	125 (65%)
<i>Commminution</i>						
3 (5%)	28 (72%)	5 (83%)	29 (94%)	61	7	65 (47%)
3 (25%)	4 (36%)	11 (69%)	52 (93%)	66	7	70 (74%)
<i>Stem</i>						
4 (8%)	10 (56%)	10 (77%)	31 (91%)	50	8	55 (48%)
0	21 (68%)	4 (67%)	44 (96%)	66	8	69 (65%)
2 (67%)	1	2 (67%)	6 (86%)	11	0	11 (79%)
<i>System</i>						
-	1	-	-	1	-	1 (50%)
5 (8%)	16 (70%)	9 (90%)	13 (93%)	41	4	43 (41%)
1 (25%)	1 (25%)	3 (75%)	19 (90%)	23	2	24 (73%)
-	11 (61%)	3 (60%)	22 (96%)	32	5	36 (69%)
-	3 (75%)	1 (33%)	26 (93%)	29	3	30 (75%)
-	-	-	1	1	-	1 (100%)
<i>System</i>						
1 (4%)	1 (100%)	-	-	1	1	2 (8%)
-	1 (100%)	-	-	1	-	1 (11%)
2 (6%)	24 (71%)	3 (100%)	26 (86%)	51	7	55 (56%)
1 (17%)	1 (25%)	8 (73%)	7 (100%)	16	1	17 (61%)
2 (33%)	5 (63%)	5 (63%)	48 (91%)	58	5	60 (78%)

dial comminution (Harrington 1975, et al 1976, Johnson et al 1968, 1973 Laros & Moore 1974 Massie 1964 Murray & Frew 1949, Niemann 1968, Rennie & Mitchell 1976, et al 1967, Sarmiento & Williams 1970, 1951) This classification does not take account the postero-lateral instability by the difficulty obtaining sufficient on of the fractures in the lateral plane frequently this system was not found to be sufficiently reliable

classification system originally used by Boyd & Griffin (1949) and later used by Tronzo (1973) has only been used in a few publications (Bosacco et al 1961, Boyd & Andersson 1961, Ecker et al 1978) Tronzo considered both the medial and postero-lateral instability. The gradings are: an increasing degree of instability but

the system is rather complicated and in the present analysis the Tronzo system did not prove to be reliable enough in the prediction of the risk of unstable fracture reduction and secondary fracture dislocation

The classification of Evans (1949) is rather simple and based on the presence of mechanical instability as related to detachments from the lesser or greater trochanter. This system has been used in numerous publications (Bremner & Graham 1958, Clawson 1957, 1964, Cram 1955, Cuthbert & Howat 1976, Dimon 1973, Dimon & Hughston 1967, Evans 1949, 1951, Foster 1958, Friedenberg et al. 1972, Harrington & Johnston 1973, Horn & Wang 1964, Jensen & Michaelsen 1975, Jensen et al. 1978, Jensen & Sonne-Holm 1980, Kuderna et al 1976, Lyle et al. 1979, Lowell 1966, Morrison et al 1978, Parker 1955, Robey

1956) The Evans classification system has been slightly modified by Jensen & Michaelsen (1975) who based the assessment on the primary X-rays after the accident and reduced the number of types from 6 to 5 by including the extremely rare fracture with a reversed oblique fracture line and large greater trochanter fragment into Type 3.

The essential result of the present comparison of the classification systems is that the modification of the Evans system offers the best prediction of the possibility of obtaining reliable anatomical reduction and the risk of secondary fracture dislocation. From the present series a new classification system could be invented based on three classes. The first class would include the stable 2-fragmentary fractures (Types 1 and 2 according to Evans), which can be anatomically reduced in both planes. The second class would contain fractures (Types 3 and 4 according to Evans) in which it is difficult to obtain reduction in one plane and the third class those with difficulty of reduction in both planes (Type 4 according to Evans). Such a classification system would be consistent with the present analysis which revealed a clear correlation between the fracture type and the possibility of fracture reduction and that mechanically unreliable fracture reduction was significantly related to secondary fracture dislocation. With five existing classification systems, however, there is no need for a new system. It is considered of greater importance to apply one of the existing systems so that the results of the fracture treatment can be compared. In this respect the classification system described by Evans with slight modifications (Figure 1) is the system of choice.

Only the sliding screw plate system (Clawson 1964, Jensen et al 1978) which allows secondary impaction was considered in the present series. With this fixation method secondary fracture dislocation is possible in all cases with fracture diastasis, leading to the establishment of bony support. In other methods of internal fixation a secondary fracture dislocation always involves either

failure of the osteoporotic bone of the head or neck or technical failure of implant. A fairly true picture of the extent of the fracture is assumed to be given in the present series, although a fracture diastasis of up to 4 mm was accepted. A definition of anatomical reduction might explain why 8 per cent (5%) of anatomically reduced fractures dislocate secondarily.

In conclusion, the Evans system (1949) in the present modification was found to give the most reliable prediction of the instability of reduction and the risk of secondary fracture dislocation of trochanteric fractures and should thus be mentioned in any analysis of the internal fixation of these fractures.

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In conclusion, the Evans system (1949) in the modified form was found to give the most reliable prediction of the instability of reduction and the risk of secondary fracture dislocation of femoral fractures and should thus be included in any analysis of the internal fixation of femoral fractures.

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STABLE TROCHANTERIC FRACTURES. A COMPARATIVE ANALYSIS OF FOUR METHODS OF INTERNAL FIXATION

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A series of 375 patients with stable trochanteric fractures were treated with the McLaughlin or Jewett nail-plate, the sliding screw-plate or Ender nailing

Technical failure of fixation was encountered in 5 per cent of the cases regardless of the method of fixation used. Re-operations were performed in less than 3 per cent of cases treated with hip implants but in 20 per cent of cases with Ender nailing, mainly because of distal slipping of the nails resulting in knee problems.

With an improved technique, however, Ender nailing can be used as successfully as any of the hip implants for the internal fixation of stable trochanteric fractures.

Key words: femoral neck fractures, internal fixation, fractures, internal fixation

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Various methods have been described for the internal fixation of trochanteric fractures. In western Europe the most commonly used methods have been the Jewett and McLaughlin nail-plates. In the beginning of the 1960s various types of telescoping devices were introduced (Böttger & Dahlke 1963, Dawson 1964, Ehlers & May 1964, Massie 1962, Schumpelick & Jantzen 1955) and the sliding screw-plate has been widely used (Jensen et al 1978). In 1970 condylocephalic nailing was introduced (Ender 1970, Ender & Simon-Weidner 1970, Simon-Weidner 1970) and has become very popular especially in middle Europe and Scandinavia.

The purpose of the present study was to compare the results of the internal fixation of

trochanteric fractures treated by the Jewett or McLaughlin nail-plates, the sliding screw-plate or Ender nailing. In the present paper only the treatment of stable trochanteric fractures (Evans 1949, Jensen 1980c) will be considered, the results obtained in unstable fractures (Evans 1949, Jensen 1980c) are discussed in a separate report (Jensen et al. 1980).

PATIENTS AND METHODS

During the period April 1st 1971 to June 30th 1979, a total of 1,646 patients with trochanteric fractures were admitted to the four departments of orthopaedic surgery participating in the study. There were 421 cases classified as stable according to the classification system described by Evans

(1949) and recommended by Jensen (1980 c) Of these 273 were undisplaced 2 fragmentary fractures and 148 displaced 2 fragmentary fractures

Five patients were treated by other methods, 33 patients died before fracture union and 8 patients were lost to follow up This study thus includes 375 patients treated by one of the four methods and followed radiologically until fracture union or technical failure was encountered

The fracture reduction was evaluated from the postoperative X ray Anatomical reduction was defined as a diastasis over the fracture line of 4 mm or less Fracture diastasis of 5 mm or more was looked for medially or laterally in the AP projection and anteriorly or posteriorly in the lateral projection The fractures were X rayed regularly until fracture union with registration of the occurrence of technical failure, telescoping of the sliding screw plate with secondary fracture dislocation and distal slipping of the Ender nails with or without displacement of the fracture Technical failure was defined as any complicating fracture

bending or breakage of the implant or dislocation of the implant in relation to the bone All fractures were evaluated by the three authors

In addition the rates of deep infection, osteitis, non union and re-operation were recorded Prophylactic antibiotics were not applied

The median age of the patients at the time of fracture was 65 years

RESULTS

The distribution of the four methods of treatment in relation to the two types of fractures is shown in Table 1 No differences concerning age, sex and fracture type were found

Deep infection or osteitis was encountered in 1 patient

Table 1 Treatment of stable fractures

Fracture type	McLaughlin nail plate	Jewett nail plate	Sliding screw plate	Ender nailing	Total
Undisplaced 2 fragmentary	78	109	32	24	243
Displaced 2 fragmentary	37	55	18	22	132
Total	115	164	50	46	375

Table 2 Quality of reduction in stable trochanteric fractures

Reduction	McLaughlin nail plate	Jewett nail plate	Sliding screw-plate	Ender nailing	Total
Anatomical in both planes	107 (93%)	147 (90%)	45 (90%)	39 (90%)	338 (90%)
Diastasis in lateral plane	6	7	3	3	19
Diastasis in AP plane	1	10	1	3	15
Diastasis in both planes	1	—	1	1	3

9 per cent (1/115) following McLaughlin plate fixation, in 18 per cent (3/164)

Jewett and in 11 per cent (1/50) after sliding screw-plate fixation. The total rate of dislocations following surgery of the hip region was thus 1.5 per cent (5/329), whereas no dislocations were encountered after Ender concephalic nailing ($P = 0.8$, Chi-square

test). The quality of fracture reduction as listed in Table 2. Anatomical reduction was obtained in 93 per cent (107/115) of cases after McLaughlin fixation, in 90 per cent (15/164) following Jewett, in 90 per cent (50/50) following sliding screw-plate and in 90 per cent (39/46) following Ender nailing. Plane diastasis was encountered in less than 1 per cent (3/375) of cases ($P = 0.99$, Chi-square test).

The results of treatment of stable trochanteric fractures are listed in Table 3. Union in the postoperative position was obtained in 93 per cent (349/375) of cases. In 10 cases telescoping of the sliding screw-plate was experienced prior to union as is indicated with this device. Secondary displacement with distal slipping of the nails was encountered in 11 per cent (5/46) of the nailings. Distal slipping without fracture displacement was encountered in 19

per cent (9/46) of cases. Distal displacement of the Ender nails often caused knee pain, necessitating re-operation.

Technical failures were encountered in 5 per cent (19/375) of the entire series with no significant difference between the methods ($P = 0.95$, Chi-square test). The type of failures are listed in Table 4. Varus dislocation of the fracture of less than 10° was encountered in about 2 per cent (7/375) of cases, whereas one fracture dislocated 30° after a McLaughlin nail-plate fixation. Secondary fracture dislocation and technical failures were observed within the first 4 weeks following the operation in 62 per cent (16/26) of cases. The remainder were encountered before the 12th week.

Re-operations were performed in 4 per cent (9/252) of cases with hip nail-plates or screw-plates with no significant difference between the methods ($P = 0.9$, Chi-square test). Re-operation was, however, necessary in 20 per cent (9/46) of patients treated by Ender nailing, either due to technical failure or distal slipping of the nails resulting in knee complaints. Bi-plane anatomical reduction was followed by technical failures or secondary displacements in 2 per cent (7/338) of cases. All three fractures reduced with diastasis in both planes dislocated secondarily compared

Table 3. Results of treatment of stable trochanteric fractures

Result	McLaughlin nail plate	Jewett nail-plate	Sliding screw-plate	Ender nailing	Total
Union in postoperative position	110 (96%)	155 (95%)	45 (90%)	39 (85%)	349
Secondary displacement with union	—	—	2	5	7
Non-union	—	—	—	—	—
Technical failure	11 (4%)	9 (5%)	3 (6%)	2 (4%)	19 (5%)
Total	115	164	50	46	375

Table 4 Technical failures following internal fixation of stable trochanteric fractures

	McLaughlin nail plate	Jewett nail-plate	Sliding screw plate	Ender nailing	
Cutting/migration < 10 mm	1	2	1		
Penetration of fem head	1	4		2	
Penetration of acetabulum		3	1		
Failure of nail- plate junction	3				
Plate loose			1		
Number of patients	5 (4%)	9 (5%)	3 (6%)	2 (4%)	19 (5)
Varus dis- location < 10°	3	2	1	1	
Varus dis- location > 20°	1				
Re-operations	1 (1%)	7 (4%)	1 (2%)	9 (20%)	15 (4)

with 38 per cent (13/34) of those reduced with diastasis in one plane only. A multivariate logistic analysis revealed a highly significant relationship between technical failures and fractures reduced with diastasis ($P < 0.00005$).

DISCUSSION

In the treatment of stable trochanteric fractures the problems involved in obtaining fracture union are minor (Ender 1970, Jensen & Sonne-Holm 1980), a fact which should encourage the use of simple methods of treatment. Internal fixation is not a great mechanical problem because an exact fracture reduction, which can usually be obtained, leads to a stable weight-transmission system in which load on the hip joint is transmitted to the femoral head through bony contact over the fracture line.

In surgery of the hip region one of the serious complications is deep infection or osteitis. This was experienced in 1.5 per cent of cases in this series regardless of the method used. Although prophylactic

antibiotics were not applied the rate is much lower than usually reported (Ender & Kjellander 1978).

In a comparison of the results obtained by different methods of internal fixation, the fracture classification system predicts the difficulty of obtaining sufficient reduction and the risk of failure of fixation should be applied. The classification system introduced by Evans (1944), based on the comminution of the fracture, medially and posteriorly, allows selection of the best method of fixation (Jensen 1980c).

Every X-ray in the present series was described by the three authors according to the classification system mentioned above. This allows comparison of the results. Most of the differences caused by the retrospective, uncontrolled design are of minor importance as this was a radiological study.

In the present series 93 per cent of fractures could be reduced without the use of internal fixation. In connection with McLaughlin's nail-plate fixation and 96 per cent united postoperative position. Technical failures following stable fractures have been

occur in 6-13 per cent (Foster 1958, & Michaelsen 1975, Laros & Moore 1976). In the present series a technical failure of only 4 per cent was experienced, and one patient developed a varus dislocation 30° due to failure of the nail-plate fixation. In a biomechanical study of Laughlin implants (Jensen 1980 a, b) very failure loads for the nail-plate connection were reported and most of the failures in the present series are also due to failure of the nail-plate at this point.

With nail-plate fixation has been followed by technical failures in 4-20 per cent of cases (Laros & Griffin 1949, Dimon & Hughston 1977, Jacobs et al 1976), although Laros & Moore (1974) claimed 43 per cent in a series of only seven cases. In the present series bony anatomical reduction was achieved in 95 per cent and technical failure occurred in 5 per cent of cases. All failures were due to displacement of the nail tip inside the femoral head or protrusion outside the components of the head or neck.

Technical failures after sliding screw-plate fixation of stable trochanteric fractures were the same as those observed in 6 per cent of cases, which is consistent with other reports (Lawson 1964, Jacobs et al 1976). Anatomical reduction was encountered in 90 per cent.

The results obtained with any of the three types of hip implants were completely satisfactory with very low failure rates and a re-operation rate of about 3 per cent. Any type of hip implant can thus be used successfully for the internal fixation of stable trochanteric fractures.

Condylorhaphy according to Ender (1970) has in mixed series of stable and unstable fractures been followed by technical failures in 7-28 per cent of cases (Hult & Larsson 1978, Kapral 1976, Kuderna et al 1976, Poigenfürst & Schnabl 1977, Wynn Jones et al 1977) and re-operations have been performed in 8-13 per cent (Poigenfürst & Schnabl 1977, Wynn Jones et al 1977). In the present series technical failures were observed in 4 per cent of cases, which is com-

parable with the failure rates experienced with hip nail plates. In addition 30 per cent of the nails slipped distally and caused knee problems leading to a total of 20 per cent re-operations (Jensen & Sonne-Holm 1980, Kuderna 1976). In the present series only 85 per cent of the fractures were reduced anatomically. It should be possible to obtain better fracture reduction and to improve the operative technique by filling out the entire medullary cavity with nails and not letting the nail ends protrude into the knee region. If this is the case then Ender nailing can also be recommended for the internal fixation of stable trochanteric fractures.

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CRITICAL ANALYSIS OF ENDER NAILING IN THE TREATMENT OF TROCHANTERIC FRACTURES

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A consecutive series of 152 trochanteric fractures treated by Ender nailing has been analysed. The mortality was 5 per cent after 3 weeks and the infection rate 2.6 per cent.

The follow-up was attended by 139 patients, 41 having had stable and 98 unstable trochanteric fractures. In the group with stable fractures, secondary displacement of the fracture or the nails occurred in 11 per cent and knee pain in 32 per cent, necessitating re-operation in 22 per cent of these patients. The corresponding figures for the unstable fractures were 64 per cent secondary displacement, 59 per cent knee pain and 46 per cent re-operations.

The results are discussed and it is concluded that, with an improvement in fracture reduction and operative technique, it may be possible to successfully treat stable trochanteric fractures with Ender nailing. However, this method cannot be recommended for unstable trochanteric fractures.

Key words femoral neck fractures, fracture fixation

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In 1966, Kuntscher introduced condylocephalic nailing of trochanteric fractures (Kuntscher 1966, 1970) using a slightly curved, ordinary medullary nail. The method is, however, not widely used (Bø 1979, Olsson et al. 1973).

Ender and Simon-Weidner further developed the method of condylocephalic nailing, applying three to five elastic, pre-bent nails with a diameter of 4.5 mm (Ender 1970, Ender & Simon-Weidner 1970, Simon-Weidner 1970). During the last 5 years the method has gained wide popularity and a number of reports, especially from Middle Europe, have recommended this internal fixation system claiming the advantages of low weight-bearing, reduced mortality and shorter hospitalization time (Bohler et al. 1975, Ender 1973, Ender & Simon-Weidner 1974,

Hult & Nilsson 1978, Philadelphia et al. 1975, Poigenfurst 1973). There have not been very many clinical reports (Kapral 1976, Kuderna et al. 1976, Poigenfurst & Schnabl 1977, Wynn Jones et al. 1977), but some papers have focused on the avoidance of technical failures without giving any background for their recommendations (Kuderna 1976, Persch & Birkner 1977).

The purpose of the present study was to perform a critical analysis of the radiological results and the clinical consequences of internal fixation of trochanteric fractures by the Ender method.

PATIENTS AND METHODS

During the period December 1st 1975 to December 31st 1978 condylocephalic elastic

nailing according to Ender was used in the treatment of 152 consecutive, trochanteric fractures.

The operative technique was that described by Ender & Simon-Weidner (1974) and Kuderna et al (1976). The patient is placed supine on a fracture table and the fracture is reduced under X-ray image intensification. The medial supracondylar region of the femur is exposed and the cortex perforated proximal to the adductor tubercle.

Three to five elastic nails 4.5 mm in diameter are introduced into the medullary cavity, diverging through the femoral neck and protruding into the subchondral area of the femoral head. In fractures with a large fragment from the greater trochanter this is fixed by introducing an additional nail in the area of the lateral femoral condyle. After completion of the operation the nails are left protruding a few millimetres outside the bone cortex in the supracondylar region.

Postoperatively early weight-bearing mobilization was emphasized although tibial traction was applied for 3 weeks in severely comminuted fractures. None of the cases included in the study was operated on by either of the authors.

The median age of the patients was 76 years (range 35-97) and 75 per cent (114/152) were women. A follow-up of 139 patients was performed, as seven patients died before fracture union and six were lost to follow-up. The mortality was thus 5 per cent (7/152) within 3 weeks.

The fractures were classified from the primary X-rays into stable and unstable fractures depending on the existence of bony support across the calcar femorale and postero-laterally (Evans 1949, Jensen 1980). The postoperative X-rays were evaluated with reference to the quality of the fracture reduction, i.e. the appearance of fracture diastasis medially, laterally, anteriorly or posteriorly over the fracture line. The reduction was considered ideal if there was a fracture diastasis of less than 0.5 cm, in all other situations the reduction was considered mechanically unstable. The positioning of the nails was also recorded. The fractures were followed up until

bony union took place or technical failure occurred. Technical failure was defined as a displacing supracondylar or femoral shaft fracture or a secondary dislocation of the fracture site. The number of infections, re-operations and complaints were recorded.

RESULTS

The classification of the fractures (Table 1); 29 per cent (44/152) as stable and 71 per cent as unstable.

Deep infection in the operation site was encountered in two cases and suppurative osteitis in another two cases. The infection rate was thus 2.6 per cent (4/152).

Full weight-bearing was obtained after 4-6 weeks. No significant relationship was found between the time taken to achieve weight-bearing, the fracture type or quality of reduction. In six patients with unstable fractures traction was applied postoperatively.

Stable trochanteric fractures were followed up in 41 out of 44 cases. Ideal reduction was achieved in 37 cases. Fracture gaps were observed in 16 per cent (7/44), medially in four and anteriorly or posteriorly in three cases.

Technical failures are listed in Table 2. Distal slipping of the nails without displacement of the fracture, as recorded in nine cases, was of no clinical significance. In one case the fracture dislocated proximally whereas bony support was achieved. Secondary impaction in four cases (Fig. 1) and secondary displacement followed fracture reduction in 8 per cent (17/212).

Table 1 Classification of trochanteric fractures

Stable 44	2-fragmentary, undisplaced	24
	2-fragmentary, displaced	20
Unstable 108	3-fragmentary without medial support	12
	3-fragmentary without postero-lateral support	42
	4-fragmentary	54

Table 2 Technical failures following Ender nailing of 139 trochanteric fractures

	Stable n=41	Unstable n=98
condylar or femoral shaft fracture		3
rotation/cutting of nails within fem head		4
penetration through cartilaginous border	2	11
		1
	3	45
	9	13
total	14	76
significant failures with re-operations	9/41 22%	36/98 37%

per cent (2/7) of insufficiently reduced cases

Knee complaints were recorded in 32 per cent (13/41) and were caused by distal slipping of the nails in eight cases

Re-operations (Table 3) were performed in 22 per cent (9/41) of the cases, a total of 10 operations. These were caused by distal slipping of the nails, except in one case where knee complaints were the only indication



Figure 1 Secondary impaction and distal slipping of the nails A The fracture is reduced with a diastasis over the fracture line. The nails are protruding too far into the knee region.



B. Secondary impaction of fracture has been obtained but one nail has slipped back causing resulting in knee pain

Unstable trochanteric fractures were followed up in 98 out of 108 cases. Ideal reduction was achieved in 20 per cent (21/105) and mechanically unreliable reduction in 80 per cent (84/105). A medial diastasis was encountered in 56 cases and anterior, posterior or lateral diastasis in 28 cases. A multivariate logistic analysis revealed no significant correlation between the stability of the reduction and the positioning of the nails

($P > 0.05$) but there was a highly significant relationship between the fracture type and mechanical stability of the fracture reduction ($P < 0.00005$). The comminution of the fracture determines the stability of the reduction.

Technical failures are listed in Table 1. One spiral fracture of the femoral shaft was treated by tibial traction. There were 9 supracondylar fractures which resulted in

Figure 2 (next page) A Three-fragmentary fracture without postero-lateral support reduced with medial diastasis. B Secondary impaction leading to bony support over the fracture line



Table 3 Re-operations following Ender nailing of trochanteric fractures

	Stable n = 41	Unstable n = 57
Nail plate fixation		1
Re-tapping of nails	1	11
Resection of nail ends		2
Removal of nails due to distal slipping	8	7
Removal of nails due to knee complaints	1	6
Number of operations	10	34
Number of patients	9 (41%)	15 (57%)
	22%	11%

hip fractures being treated by nail-plate fixation, and in addition a AO-angular plate was applied to one of the supracondylar fractures.

Secondary fracture displacement was caused by distal slipping of the nails in 45 cases and penetration through the cartilaginous border of the femoral head in 11 cases. The latter complication necessitated a nail-plate osteosynthesis in one case. Ideal reduction was followed by secondary displacement of the fracture in 15 per cent (3/20) of the cases, whereas a mechanically unreliable reduction led to technical failures in 69 per cent (59/85) (Figure 2). A multivariate logistic analysis revealed a highly significant relationship between mechanically unreliable reduction and the appearance of technical failures ($P < 0.00005$). No significant correlation between the fracture type and technical failures was found.

Varus angulation was encountered in eight cases, three being less than 10° and five between 20° and 30° (Figure 3). Secondary fracture displacement was thus observed in a total of 62 per cent (60/97) of cases. Significant technical failures occurred in 64 per cent (63/98).

Knee complaints were recorded in 59 per cent (57/97) of cases, and were due to distal slipping of the nails in 40 cases. In 27 cases re-operations were necessary.

Re-operations were performed, as listed in Table 3, in 46 per cent (45/98) of patients with a total of 54 operations, because ten

patients were operated upon twice and 11 patients three times. Nearly all operations were caused by distal slipping of the nails and knee complaints. Ideal fracture reduction was encountered in nine of the re-operated patients.

DISCUSSION

It has been claimed that Ender nailing has the following advantages: a low infection rate, a small demand for blood transfusion, early mobilization with full weight-bearing, reduced hospitalization time and reduced mortality (Bohler et al 1973, Ender 1973, Ender 1973, Ender & Simon-Weidner 1973, Philadelphia et al 1973, Poigenfurst 1977).

In the present series deep infections in the knee region were encountered in 26 per cent of the cases. This is in the same range as the 35 per cent reported after McLaughlin nail plate fixation, where the infections were located in the hip region (Jensen & Michaelsen 1975).

The 5 per cent postoperative mortality after 3 weeks is not significantly different ($P > 0.05$, Chi-square test) than the 9 per cent reported in a large overall survey of hip fractures by Jensen & Tondervold (1977).

A classification system based on the mechanical stability of the fracture (Jensen 1949) was applied as recommended by Jensen (1980). Only about 30 per cent of the fractures in this series were considered to be



3A Three fragmentary fracture without postero-lateral support reduced with anterior diastasis not introduced into the subchondral area



Figure 3B Distal slipping of nails resulted in secondary varus dislocation

while Kuderna et al (1976) reported 85 per cent and Wynn Jones et al. (1977) 85 per cent. The main problem in the internal fixation of stable trochanteric fractures is to

obtain an exact reduction. This was achieved in 84 per cent and secondary displacement of the fracture and the nails occurred in 12 per cent of these cases.

Knee complaints are rather common following condylo-cephalic nailing (Bø 1979, Kapral 1976, Kuderna 1976, Wynn Jones et al 1977). In the present series 32 per cent of the patients with stable fractures suffered from knee pain, often necessitating re-operation. This prevents early mobilization and prolongs hospitalization time, although most of the re-operations were nail removals. The problems involved in obtaining fracture union in stable trochanteric fractures are minor (Ender 1970) and Ender nailing is theoretically a fairly simple fixation method. However, it should be emphasized that a mechanically reliable reduction together with a perfect operative technique are the prerequisites for the attainment of good results. Thus, with an improved surgical technique satisfactory results might be obtained with Ender nailing in stable trochanteric fractures.

In unstable trochanteric fractures internal fixation is a much greater problem, and secondary displacement or implant failures with subsequent re-operations occur rather frequently (Jacobs et al 1976, Jensen & Michaelsen 1975, Laros & Moore 1974). In former reports on Ender nailings the number of technical failures have ranged between 12 and 28 per cent (Hult & Nilsson 1978, Kapral 1976, Kuderna et al 1976, Poigenfurst & Schnabl 1977, Wynn Jones et al 1977) and re-operations have been performed in 8-13 per cent of cases (Poigenfurst & Schnabl 1977, Wynn Jones et al 1977). Kuderna (1976) reported as many as 16 per cent nail removals due to knee complaints. In the series of Kuderna et al (1976) and Wynn Jones et al (1977) however, most of the fractures were stable.

In the present series the rate of technical failures was 64 per cent. The multivariate logistic analysis revealed that the probability of technical failure in both stable and unstable fractures is determined by the mechanical reliability of the fracture reduction. The fracture type is such significantly influences the quality of the reduction. It has been pointed out that secondary impaction of

the fracture is to be expected following Ender nailing (Kapral 1976, Martinek et al 1976, Persch & Birkner 1977, Poigenfurst & Schnabl 1977, Wynn Jones et al 1977). Fracture impaction was observed in 4 per cent of cases in the present series, while secondary varus dislocation was found in 1 per cent. This could be acceptable if the fracture impaction did not lead to distal locking of the nails and subsequent knee pain necessitating removal of the nails. As a consequence of re-operations, hospitalization time is prolonged and in addition, the benefit of early weight-bearing mobilization is lost.

From the results in this series Ender nailing can not be recommended for internal fixation of unstable trochanteric fractures. An altered technique with a dimensional bending of the nails, as recommended by Kuderna (1976) is not liable to solve the problems. Persch & Birkner (1977) emphasized the importance of exact reduction of the unstable 3- and 4-fragmentary fractures; however, it is extremely difficult to achieve a mechanically reliable reduction, especially for orthopaedic surgeons with limited skill. These are the ones most often operating on patients in a hard working emergency department in the Scandinavian countries.

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INTERNAL FIXATION VERSUS ENDOPROSTHESIS
THE TREATMENT OF FEMORAL NECK
FRACTURES IN THE ELDERLY

A Prospective Analysis of the Comparative Costs and
Consumption of Hospital Resources

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The consumption of hospital resources and the costs involved in treating femoral neck fractures in the elderly were studied and a comparison was made between internal fixation (von Bahr screws) and primary prosthetic replacement (Christiansen's endoprosthesis). The 1 year results of screw fixation were excellent or good in 55 per cent of the patients, fair in 17 per cent and poor in 28 per cent, compared with 79 per cent excellent or good

and reoperations in the internal fixation group. Considering the total costs, prosthetic replacement was found to be 1.6 times more expensive than internal fixation.

Key words: cost analysis, femoral neck fractures, internal fixation, prosthetic replacement

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Two most widely accepted types of operative treatment for femoral neck fractures in the elderly are internal fixation and prosthetic replacement. Due to the increasing cost of medical care and the limited resources available it is interesting to compare the consumption of hospital resources and the cost involved in two methods of treatment to ascertain the optimal method of treatment from both the medical and economic viewpoints.

PATIENTS AND METHODS

One hundred and four patients, older than 67 years of age, admitted during the period

1974-1976 for treatment of femoral neck fractures were randomly allotted to one of two treatment groups. Internal fixation was performed in 51 patients (mean age 78 years) using von Bahr screws (von Bahr et al. 1974, Søreide et al. 1979b), and replacement arthroplasty was performed in 53 patients (mean age 78 years) using a Christiansen trunnion bearing hip prosthesis (Christiansen 1969, Søreide et al. 1975).

The medical records of the patients were evaluated in March 1978. The construction of a cost analysis system for internal fixation and prosthetic replacement was described in a previous paper (Søreide et al. 1979a). The consumption and costs.

For the calculation of costs, we have identified the basic costs per patient day of maintaining a standard bed in our 1050 bed hospital. In 1976 this expenditure amounted to Nkr 482. The other

Table 1 Costs of primary admission of patients with femoral neck fractures

	Costs per patient ¹	
	Internal fixation (n=51)	Endoprosthesis (n=53)
Stay in hospital	8.6	19.2
Operation	0.7	4.6
duration	0.2	0.7
implants	0.5	3.4
blood transfusions	0.0	0.5
X ray examinations	0.9	1.1
Laboratory tests	0.5	1.0
Antibiotics	0.05	0.4
Other costs ²	0.3	0.3
Total	11.05	26.6

¹All costs are expressed using the basic costs of a hospitalization day in a regular ward as a unit (1 day = 482 Norwegian kroner in 1976).

²Including intensive care

categories of expenditure are given in units of this cost

Student's *t* test (two-tailed) has been used for the statistical analysis unless otherwise stated

RESULTS

The admission procedures and the initial treatment (tibial traction), daily nursing and the work of medical staff (except for the operative procedures), physiotherapy and secretarial work were found to be identical for the two groups. These parameters were therefore excluded from further analysis.

Clinical results In this series of patients (Søreide et al 1979a) internal fixation was found to be a less time-consuming operation and was followed by a shorter hospitalization time. The failure rate after 1 year of follow-up was 25 per cent (13/51) (technical failures, non-union and femoral head necrosis). Primary prosthetic replacement was a more time-consuming operation and was associated with a requirement for blood transfusions, but involved fewer reoperations. The failure rate was 9 per cent (5/53) (postoperative dislocations). The mortality rates recorded 16 and 12 months after the operations were

similar for the two groups with 9 deaths (18 per cent) in the internal fixation group and 10 deaths (21 per cent) in the prosthetic group 1 year after the operations.

Consumption of resources during the first 6 months in hospital Prosthetic replacement was associated with a significantly longer hospitalization time ($P < 0.005$), as well as higher operation costs including blood transfusions ($P < 0.001$), number of laboratory tests ($P < 0.005$) and use of antibiotics ($P < 0.005$) (Table 1). The total cost per patient treated was 24% higher in the prosthetic group compared with the internal fixation group.

Follow up The time from operation to the most recent follow-up was noted for all patients in the internal fixation group. The mean follow-up period was 17 months compared with 13 months for the prosthetic group. This difference was statistically significant ($P < 0.005$). The number of outpatient visits (4 versus 2) and number of X ray examinations (4 versus 2) were significantly higher in the prosthetic group ($P < 0.005$). Calculated on a per patient basis (Table 2) the outpatient care amounted to the cost of 14 hospitalization

Table 2 Costs of postoperative follow-up

	Costs per patient ¹	
	Internal fixation (n=43)	Endoprosthesis (n=40)
Visits to outpatient department	0.7	0.4
X-ray examinations	0.9	0.5
Total	1.6	0.9
Average costs related to the original number of patients in the group	1.4	0.7

¹See Table 1

in the internal fixation group and 0.7 in the prosthetic group.

Readmissions and reoperations. Fifteen patients in the internal fixation group and six in the prosthetic group required subsequent admissions to the hospital because of fracture-related complications ($P=0.03$, t 's test) (Table 3). Eleven patients in the internal fixation group needed further operations (nine prosthetic replacements) compared with three patients in the prosthetic group ($P=0.02$, Fisher's test). The

costs of readmission were somewhat higher than the costs of the first admission, but the costs per readmitted patient were similar in the two groups. Based on the original number of patients in each treatment group, the average costs per patient remained lower in the endoprosthetic group due to the smaller number of readmissions in this group.

Total costs of treatment. Total costs per patient in the two groups are given in Table 4. Prosthetic replacement was found to be 1.6 times more expensive than internal fixation.

Table 3 Costs of readmissions expressed as average costs per readmitted patient

	Costs per readmitted patient ¹	
	Internal fixation (n=15)	Endoprosthesis (n=6)
Stay in hospital	15.3	16.5
Reoperation	3.6	1.8
duration	0.6	0.3
implants, etc	2.5	0.8
blood transfusions	0.5	0.7
X-ray examinations	0.9	0.6
Laboratory tests	0.7	1.1
Antibiotics	0.2	0.3
Other costs ²	0.04	1.4
Total	20.74	21.7
Average costs related to the original number of patients in the group	6.1	2.5

¹See Table 1²Including intensive care

Table 4 Total costs of treatment of acute femoral neck fracture in elderly patients. Costs are given per patient related to the original number of patients in each treatment group and are expressed using the basic costs of a hospitalisation day in a regular ward as a unit

	Costs per patient ¹	
	Internal fixation (n=51)	Endoprosthesis (n=53)
Primary admission	11.05	26.6
Follow up	1.4	0.7
Readmission	6.1	2.5
Total	18.55	29.8

¹See Table 1

DISCUSSION

Most reports on operative treatment of femoral neck fractures and on comparisons of different methods are based on analysis of medical factors only. In spite of fairly high failure rates, internal fixation has been widely advocated and it has been accepted that a certain number of patients require further surgical treatment (mostly with secondary prosthetic replacement) due to complications or failures following the osteosynthesis.

As an alternative method, primary prosthetic replacement has been recommended for treatment of femoral neck fractures in the elderly as the results may be more reliable (Johnson & Crothers 1975, Søreide et al 1979a). Despite the more extensive tissue trauma and the more time-consuming operation compared with internal fixation, comparable mortality rates are encountered in randomized series (Søreide et al 1979a). The results of hemiarthroplasty, however, deteriorate significantly with increasing follow-up time (Søreide et al 1980).

In the present series, primary failures (non-unions and avascular necrosis) resulted in reoperations in 21.6 per cent of the patients, a figure which seems comparable with those in other reports (Johansson 1964, von Bahr et al 1974). In addition, the number of cases of avascular necrosis may be expected to increase with time (Johansson 1964, Massie

1973). In the prosthetic group reoperations were necessary in 5.6 per cent of the patients. A longer follow up reveals a lower quality of the results, and complications which may lead to further reoperations (Søreide et al 1980).

Generally, it may be concluded that both osteosynthesis and prosthetic replacement are acceptable methods and both seem to provide satisfactory solutions to this difficult problem. If it is not possible on purely medical premises to decide which method is superior, then it is obvious that economic considerations become more interesting. Given the limited resources available, they are not only important, but probably decisive in the choice between the two treatment alternatives.

We contend not only that the advantages of primary prosthetic replacement compared with internal fixation of femoral neck fractures in the elderly are not confirmed (Søreide et al 1979a), but that this method is accompanied by a substantial economic cost. This is a good example of the difficulties often met with in modern surgical decision-making where the advantages associated with one treatment may be so slight that the corresponding expenditure may not be justified.

The present study suggests that the most significant cost entity in the treatment of the initial hospitalization period is the longer duration of stay in the prosthetic group, which reflects an increased risk

operatively in this group (Søreide et al 1980). On the other hand the mortality rates for the groups are equal. This finding indicates that we can now apply surgical procedures which are more elaborate and invasive without increasing the mortality.

Thus can however only be achieved by considerably increasing the consumption of resources and the costs.

Primary prosthetic replacement was in this interim study found to be a more invasive type of treatment than internal fixation as fewer patients were readmitted to hospital. However this finding and the associated reduced costs for the prosthetic group do not compensate for the great difference in costs involved in the first stay in hospital. On the other hand it may be said that a readmission irrespective of the direct or indirect additional burden on the hospital system. One may contend that once admitted the disability of 19 days in hospital for the prosthetic group is not more than marginally different from the disability of 9 days for the internal fixation group. Similarly follow up is less expensive for the prosthetic group. Thus may be of potential benefit to a hospital with limited resources.

As already mentioned a longer follow up may modify the ratio of expenditure between the two groups. An increasing number of cases of femoral head necrosis will increase the costs of internal fixation. On the other hand the results of prosthetic replacement also improve. Thus we may assume that the ratio of expenditure between the two treatment groups will not be significantly altered with increasing follow up time.

The method of internal fixation used in the present series is probably not the optimal. Analysis of a method which gives a more rigid fixation namely hip screw fixation is in progress. With a more careful reduction procedure combined with a rigid fixation the primary failures following internal fixation

could be reduced to 5 per cent (Alho et al 1980). After 1 year the fair and poor results together amounted to 18 per cent. It appears that improvements in therapy are to be expected with this line of treatment which is moreover the superior alternative from the economic point of view.

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ASEPTIC LOOSENING OF THE MONK HIP PROSTHESIS

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In a preliminary report concerning 104 Monk arthroplasties satisfactory results were found within an observation time of 16 years (Hansen & Rechnagel 1977). However an early tendency for aseptic loosening was recorded. At a follow-up of the same patients after 5 years it was found that 17 patients, with their primary prostheses in place, had died. Of the remaining 86 prostheses not less than 50 per cent had been removed because of loosening causing symptoms. Furthermore at re-examination of 39 patients with 43 of the primary prostheses still *in situ* radiological and clinical evidence of progressive aseptic loosening was present.

The aetiology of the loosening is discussed and it is suggested that wear of the polyethylene cap plays an important role. It is concluded that the "soft top" Monk prosthesis cannot be recommended for replacement arthroplasty of the hip.

Key words: aseptic loosening, Monk hip prosthesis, revision arthroplasty, uncemented hip arthroplasty.

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Aseptic loosening following total hip replacement is a well known complication. The prosthetic design, the operative technique and postoperative load and wear are essential factors in the aetiology. In the choice of a prosthesis the object is to ensure, as far as possible, that symptoms of loosening do not occur in the number of years the patient can be expected to live after the arthroplasty. In February 1974 we started to use the Monk prosthesis, which is a one-piece block design. In the original design it consists of a metal femoral component with the head fixed in a polyethylene cup (or cap). The advantages of this prosthesis are that it can be inserted without the use of cement, thus avoiding the risk of infection, and that the operative procedure is the same as for the more conventional arthroplasty. In a previous follow-up report concerning

the first 104 operations Hansen & Rechnagel (1977) found that 76 per cent of the patients had an excellent result, but after only 16 years eight of the prostheses had been removed because of aseptic loosening. Subsequently, the incidence of loosening causing clinical symptoms severe enough to necessitate revision increased, and as a consequence the use of the Monk prosthesis was abandoned in January 1978. We have re-examined and further analysed the previously published material and discuss here the problems concerning loosening of the uncemented standard Monk prosthesis.

PATIENTS AND METHODS

The hospital records of the patients included in the previously published series (Hansen &

Rechnagel 1977) — 104 operations in 94 patients performed from February 1974 to September 1976 — were reviewed. Information about patients who had died within the period of observation was obtained from the National Register. The material was divided into three groups.

Group A consisted of 18 prostheses in 17 patients who had died during the period of observation. Evaluation was based on notes from the outpatient records.

Group B "the revision group" consisted of 43 prostheses in 38 patients who had undergone a revision operation. Information regarding the indications for the revision, the operative findings and the postoperative course were obtained from the hospital records.

Group C "the re-examined group" consisted of 43 prostheses in 39 patients. These patients with the primary prostheses *in situ* were clinically and roentgenologically examined by the authors.

The clinical results of this examination were compared with the results from the follow up in 1976 (Hansen & Rechnagel 1977) using the Merle d'Aubigné scoring system (Merle d'Aubigné & Postel 1954). Comparison between the radiological changes in the revision group and "the re-examined group" was made.

In the revision group the first postoperative X ray in the A-P projection was compared with the X ray taken just before the revision. Measurement of stem tip migration, resorption of the calcar and the radiolucent zone was used as a sign of radiological loosening (see legend to Figure 1). In "the re-examined group" the comparison was made with the X-ray from the actual re-examination.

RESULTS

Table 1 shows the distribution in the groups A, B, and C at the follow up in 1979. Figures from the follow-up in 1976 (Hansen & Rechnagel 1977) are shown for comparison.

Group A — Dead without revision of prosthesis

Seventeen patients with 18 prostheses had died during the observation. Two patients died pulmonary embolism shortly after. The other deaths were all arthroplasty.

From the records it was found that patients in this group had severe walking and radiological signs of further two patients had been revision operation before they died.

Group B — "The revision group"

By 1979, 43 of the prostheses in had been removed due to loosening. Indications for revision became 62 months (average 33 months) primary operation. The revision meant an extra hospitalization of 13 average.

In all patients the indication was pain after a period of good function. Patients had pain at rest but pain walking was the most common. Radiologically, considerable resorption of the calcar was present and the prosthesis had tilted into varus so that the stem invaded the lateral cortex.

When an exchange operation was considered it was required that the E was normal and that no local clinical infection were present.

The reoperations were performed

Table 1 Monk arthroplasties at follow-up

	1976	1979
A Dead without revision of primary prosthesis	8	18
B Revision performed	8	43
C Primary prosthesis still functioning	88	43
Total	104	104



Figure 1 (a) First postoperative X ray after insertion of a standard Monk prosthesis in a 69 year old patient with osteoarthritis (26 06 1974) (b) Same patient before revision operation because of aseptic loosening (09 04 1976) Measurement of stem tip migration resorption of the calcar and the radiolucent zone performed

same posterior approach as the primary operation. In all cases the prostheses were easy and easy to remove. During the operation it could be demonstrated that cement took place both between the prosthetic components and between the ethylene cap and the acetabulum during flexion. The capsular tissue was thickened with a large amount of proliferating granula

tion tissue was found in the medullary canal and in the acetabulum. Biopsy of the capsular tissue was not routinely performed but when it was done it showed a histiocytic reaction with refractile particles, which were thought to be debris from wear of the polyethylene.

Cultures for aerobic and anaerobic bacteria were made during the majority of the revisions. In one case *Staphylococcus albus* was



Figure 2 Removed standard Monk prosthesis showing pronounced wear after 36 months

discovered. In this patient pus was evident at the operation and a Girdlestone resection arthroplasty was performed. The removed prostheses all showed signs of wear on the outer surface of the polyethylene cup due to articulation in the acetabulum. Figure 2 shows a very pronounced case. This prosthesis was removed 3 years after insertion.

Table 2 shows the type of revision procedure used. In seven cases the implant was removed and the patients left with a resection arthroplasty. In one case this was

due to infection as mentioned above. In the remaining six cases a new replacement was considered to be too extensive and considering the patients' ages and presence of other debilitating diseases these patients developed a postoperatively in spite of negative operative cultures. In 36 cases insertion of a new prosthesis was performed. In February 1978 we used a cemented prosthesis. After the department achieved a clean air flow the Monk prosthesis was abandoned and the Müller metal-polyethylene prosthesis with a ceramic head was used in the revision operations.

At the reoperations special care was taken during the preparation of the medullary canal and whenever possible a long stem component was used in order to avoid the femoral shaft where the tip of the primary prosthesis had eroded the cortex.

Postoperatively bed exercises were started on the second day, sitting was allowed on the third day and walking was permitted from the tenth day. One patient was out of bed 7 days after surgery and for his femur just below the tip of the prosthesis. The fracture healed after 8 weeks in situ. There has been no fatal embolism or postoperative deep infections following reimplantations.

Group C - 'The re-examined group'

At follow up 43 of the primary prostheses 39 patients were still in place. As a consequence of the re-examination these patients

Table 2 Revision procedures for loose Monk arthroplasties

Resection arthroplasty (Girdlestone)	7
New cemented Monk prosthesis	15
New long stem Monk prosthesis	1
Müller's prosthesis with ceramic head	20
Total	43

advised to have a revision operation. The living patients are still satisfied with their and none of them complains of pain. The majority have only moderate pain at all during daily activities. The age at follow-up was 66 years and the level of activities must be related to this.

Table 3 shows the situation before and after the primary operation according to the results of Merle d'Aubigné & Postel (1956). It is evident that there has been some loss of function in this the most successful group of patients during the period of observation from 1976 to 1979. The loss of mobility is that 50 per cent of the patients required help, for example, with putting on stockings or tying shoe laces. The main reason for the score for walking being only 2, meaning that the patients are dependent on sticks or crutches, is that this group of patients are elderly and suffering from other conditions, especially knee arthrosis.

Table 4 shows the radiological measurements of prosthetic migration. In

spite of the shorter period of observation the signs of loosening before reoperation in the revision group were significantly greater compared with the re-examined patients with their primary prostheses still *in situ*. Also it is our experience that implants with minimal osteolysis and migration are clinically the best. On the other hand several prostheses with marked osteolysis and calcar resorption were still asymptomatic. Thus the indications for a revision cannot be established purely on radiological findings.

Five patients with subcapital femoral neck fractures and 20 with femoral head necrosis following fracture were evaluated in order to see if the presence of a non-arthrotic acetabulum at the time of the primary replacement was of importance. The patients were, however, equally represented in the revision group and in the re-examined group. To estimate if the state of activity of the patients was of any importance we compared age and sex in the revision group and the re-examined group. No difference was found.

Table 3 Average points for function - pain, mobility walking - according to Merle d'Aubigné 43 primary arthroplasties in the re-examined group

	Preoperative	1976	1979*
Pain	1.2	5.7	5.1
Mobility	3.3	5.5	4.6
Walking	2.3	4.3	3.7

*42 arthroplasties, in one case re-examination was not performed

Table 4 Average figures for the migration of the primary prosthesis comparing first and last postoperative X-rays

	No of implants	Time of observation	Stem-tip migration	Resorption of calcar	Radiolucent zone
Revision group	43	32 mths	7.2 mm	11.3 mm	6.5 mm
Re-examined group	43*	53 mths	4.5 mm	5.6 mm	3.1 mm

* In two patients X-rays were not available

DISCUSSION

Several recent papers have shown that both uncemented and cemented total hip replacements in some cases become loose and painful after good primary results. Ring (1974) reports 3.7 per cent revisions due to loosening in his primary series. In other series the frequencies are considerably higher (Lindholm & Puranen 1976). In 1042 McKee-Farrar prostheses Dandy & Theodorou (1975) found 6.6 per cent requiring revision after 2 years. The low friction metal-polyethylene prostheses seem to give better results. Nolan et al (1975) found revision necessary in only 0.5 per cent after 2 years in 3204 Charnley arthroplasties. Although a longer observation time will undoubtedly increase the number of loosening, as seen in John Charnley's long-term results (1979), we find the frequency of aseptic loosening to be so high in the present material that we suspect the design of the Monk prosthesis to be especially unfavourable.

The presence of wear products from metal or polyethylene around the prosthesis is presumed to play an important role in the aetiology of loosening. The wear particles appear to cause an histiocytic reaction with formation of granulation tissue, bone necrosis and bone absorption leading to loosening. In experimental hip arthroplasty in dogs Mendes et al (1974) described the tissue reaction caused by the polyethylene particles around the implant. Dahl & Mikkelsen (1976) had poor results with the Oscobal system for hemiarthroplasties because of extensive wear of the polyethylene head. Recently Wroblewski (1979) demonstrated failures where high-density polyethylene articulated against bone or cartilage. He stated that there can be no justification for the use of polyethylene in direct contact with a normal or abnormal acetabulum. Willert et al (1978) showed how wear products are transported away from the implant through the perivascular lymphatic spaces. In their opinion excessive release of wear products will overload the transportation capacity of the reticuloendothelial system leading to an

accumulation of wear particles and implant accelerating the phenomenon of loosening. On the other hand if the particles are low an equilibrium may be reached.

The design of the Monk prosthesis with the polyethylene cup (or cap) against the metal head and the cup. This restricts the impingement of the femoral neck on the socket during hip flexion of about 60 degrees, after which movement takes place between the polyethylene and the

In our revised cases we constant found considerable wear on the outer surface of the polyethylene (Figure 2). The capsule around the prosthesis was thick and which probably further restricts movement between the prosthesis components and accelerates the wear. The implant was embedded in granulation tissue and biopsies showed foreign body reaction and refractile particles.

We assume that the motion in our satisfactory prostheses mainly takes place between the metal head and the polyethylene cup. At re-examination however we found no significant radiological signs of bone resorption (Table 4) and a progressive loss of function (Table 3).

The original "soft top" type of prosthesis with minor modifications is still available. A "hard top" type with a metal head pressed over the top of the polyethylene cup is also available. It can be inserted with or without cement. The brochure from D. Howe & Co. Limited (1979) it is stated that it will complete the Monk hip system thus removing the need for a "hard top" type of prosthesis to accommodate osteoarthritic patients with marked roughening of the articulation and a life expectancy of longer than 5 years.

In our experience the "soft top" type has been very unsatisfactory. In patients with osteoarthritic hips, as well as in patients suffering from sequelae after femoral fractures, almost 50 per cent of the prostheses had to be removed within 5 years (mean 18 months) because of aseptic loosening.

ptoms. Although the debris problem subtly is less in the metal covered design know that especially in active patients an erosion will take place and cause problems when a metal head is articulating in acetabulum (D'Arcy & Devas 1976). Based on numerous reports, especially Charnley's 1979 long-term results, we therefore conclude the conventional cement fixated low friction prosthesis offers a better alternative in treatment of osteoarthritis of the hip.

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WEIGHT REDUCTION BEFORE HIP REPLACEMENT

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Weight reduction before surgery on obese patients has been widely recommended, but its practical possibilities have not been elucidated so far. Operation for osteoarthritis of the hip was offered to 130 obese patients on the condition that they reduced their weight to normal. After a minimum observation period of 1 year the weight had returned to normal, and operation was performed, in 73 per cent. Only 5 per cent gave up losing weight. The weight reduction averaged 8.6 kg (1-25 kg). A weight reduction of up to 15 kg was achieved within less than a year by eating less (94 per cent) or changing the dietary habits (88 per cent), and only 3 per cent had to be admitted to hospital.

Key words: hip surgery, obesity, preoperative weight reduction.

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operative risk and the incidence of operative complications are considered to be increased in obese persons, and preoperative weight reduction has been recommended by Adolfson (1970), Kasper & Irner (1974), and Feinstein & Habermann (1977). In total hip replacement by the Charnley method, moreover, weight reduction is desirable for technical reasons, as the subcutaneous tissue lateral to the greater trochanter, especially in women, may be thick, even up to 10 cm. It is therefore difficult to suture, and haematomas are apt to accumulate at this site. The tendency for haematomas increases with the thickness of the subcutis (Ponsford 1974, Sakai & Kistutz 1976). At the operation the greater trochanter is displaced laterally, so that it protrudes into the subcutaneous tissue. Furthermore, postoperative mobilization is hampered when the patient is not obese. An additional factor is that the various types of total prostheses for the femur are dimensioned in accordance with a given maximum body weight, and in some cases this alone is a sufficient reason for weight reduction. Within

the field of internal medicine it has been demonstrated several times that appreciable weight reduction can be achieved in a short time (Genuth et al 1974, Maaga & Mogensen 1970).

PATIENTS AND METHODS

The present study was carried out during the period 1st April 1975-1st April 1978 in the Department of Orthopaedic Surgery O, Odense University Hospital, Odense, Denmark. In the case of overweight patients, it was stipulated that the weight must be reduced to (height in cm less 95) kg before hip replacement. This corresponds to

indications made the operation particularly urgent. The difference between the weight at admission and that measured when the patient was first seen constituted the actual weight loss. The patients were given advice and guidance on weight reduction at the first consultation but the rest was left up to them in some cases with the support to their GP.

In order to assess the results it is necessary to distinguish three groups of patients:

Table 1 Incidence of overweight in 395 patients referred for total replacement of the hip during the year period April 1975-1977 (Group A)

	Not overweight	Overweight	
Not offered operation	58 (32%)	122 (68%)	180
Offered operation	85 (40%)	130 (60%)	215
Total	143 (36%)	252 (64%)	395

Group A During the period April 1975 to April 1977, patients were selected for replacement surgery from among 411 newly referred persons with osteoarthritis of the hip. Of this number 395 had their height and weight measured. The achievement of weight reduction and subsequent operation, as well as the reasons why operation was not performed, were analysed after 1 year's observation in 130 overweight patients among the 215 to whom operation was offered.

Group B The time taken for the required weight reduction was recorded among the patients who underwent operation during the period April 1975-1978. All 3 years had to be included to get sufficient representation of substantial weight reduction. During this period operation was performed on 350 patients, 139 of whom were overweight initially. The time taken for weight reduction was recorded by the overweight patients who kept account of their weight at home at intervals of a week or two.

Group C One hundred randomly chosen overweight patients were asked how they had reduced their weight, in such a way that they

could answer "yes" or "no", and so that be analysed, in percentage how many had given procedure.

RESULTS

Group A Among the 395 patients 215 offered operation and 180 were not. This gives the incidence of overweight in the groups. Among the 215 patients 60 per cent were overweight and among the 180 patients 33 per cent. This difference is not statistically significant ($\chi^2 = 2.26$, $0.1 > P > 0.05$). To the body weight did not essentially influence the decision to offer operation.

The achievement of weight reduction after thereby of the operation, may be seen in Table 2. Of the 130 overweight patients whom operation was offered 78 per cent were operated upon after a 1 year observation period. Only 5 per cent gave up weight.

Table 2 Accomplishment of weight reduction in 130 overweight patients offered operation during the period April 1975-1977 (Group A). The reasons why 35 patients had not been operated on by April 1978 are given

Waiting, weight normalized	7
Waiting, weight not normalized	6
Weight reduction given up	6
Pain abated	6
Complicating disease	6
Operated on in another hospital	6
Waiting for another primary operation	2
	2
Total not operated	35
Operated	95
Total	130

— end of patients

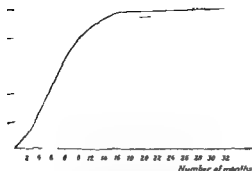


Figure 1 Cumulated percentage of operated patients in relation to time elapsing from the first clinical examination until the day of operation

However, the weight reduction sometimes exceeded more than 1 year. A total of 3 years elapsed from the time that the first patients were admitted to the study. Figure 1 shows how long the patients waited from the time of the first consultation until operation. Only 14 per cent waited for more than 1 year. A lack of capacity made it impossible to operate on patients as soon as they had achieved the desired weight reduction. The actual time taken for weight reduction may be seen from Figure 2. A weight loss of 15 kg or less was achieved within 1 year. The greater the necessary weight loss, the longer the time required. Judging by the median values, the results obtained correspond to a mean weekly weight loss of 0.9 kg.

Group B Table 3 sets out the extent of the weight loss. The majority only needed a

Table 3 Extent of weight loss among 139 primarily overweight patients operated on during a period April 1975-1978 (Group B). Mean weight reduction 8.6 kg

Weight loss in kg	Number of patients	Per cent
0-5	42	30%
5-10	48	34%
10-15	38	20%
15-20	18	13%
20-25	3	2%

Number of weeks

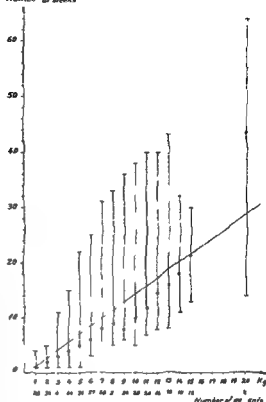


Figure 2 Number of weeks spent in reducing the weight

Table 4 Mode of weight reduction and conditions during reduction in 100 obese patients with OA of the hip (Group C)

Weight reduction achieved by	Number of patients
eating less	94
change in diet	88
checked by general practitioner	42
anoretics	11
Weight Watchers	5
exercise	10
hospitalization	3
Conditions during weight reduction	
pain abated	20
complications (depression)	15

minor reduction in weight. During the 3-year period 139 patients underwent operation after weight reduction. Among them 90 (64 per cent) had to lose less than 10 kg. Only three patients achieved a weight loss of more than 20 kg.

Group C The methods of achieving the weight loss even major weight loss were very simple (Table 4). Most patients merely ate less (94 per cent) and altered their dietary habits (88 per cent). Forty-two per cent frequently consulted their own doctor for advice and check weighing. Three per cent had to be admitted to a department of internal medicine in order to lose weight.

After the weight reduction 28 per cent stated that the pain had decreased and only 15 per cent had complaints in connection with their weight reduction.

DISCUSSION

According to several authors the operative risk is increased in obese persons (Adolfson 1970, Strauss & Wise 1978) while others have reported that this risk is not increased or only moderately so (Andersen 1971). In the present study no attempt was made to elucidate this problem but owing to the special reasons for achieving weight reduction before hip replacement it was done to ascertain how far in practice body weight can be reduced preoperatively. In at least 73 per cent of our obese patients the weight was reduced to normal.

The weight reduction was on average 0.9 kg weekly with little help from the health sector. However patients with osteoarthritis

of the hip probably make up a pre-operative group. Their severe pain made them motivated for operation and from their fellow patients they learn about the results of operation.

The long waiting times in departments of orthopaedic surgery where hip replacement is carried out can be used to achieve normalizing the body weight of the candidates for operation.

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TOTAL FEMUR REPLACEMENT IN SARCOMA OF THE DISTAL END OF THE FEMUR

KATZNELSON & J NERUBAY

Chaim Sheba Medical Center, Tel-Hashomer, Tel-Aviv University Medical School, Israel

Five patients with sarcoma of the distal end of the femur were treated by a total resection of the femur and its replacement by an endoprosthesis. This

vincristine. Surgical removal of pulmonary metastases and other local recurrences was performed where and when possible.

The functional results were excellent in four and poor in the remaining patient. All of the patients rapidly achieved physical rehabilitation and developed a stable and painless gait.

This approach to the treatment of osteogenic sarcoma attempts to eliminate the primary tumor, the micrometastases and the overt metastatic disease, leaving the patient to follow as normal a life as possible, which is not the case when a high thigh amputation or a hip disarticulation is performed.

Key words: endoprosthesis, sarcoma, total resection of femur

Accepted 17 in 80

ck resection of a primary bone tumor followed by a reconstructive procedure is not a new method. Kronecher in 1896 reported the first replacement of a sarcomatous fibula with an ivory stem. Following this a great variety of methods have been reported for the resection of bony regions according to the skill and ingenuity of the surgeons (Wilson & Lance 1965, Merle D'Aubigné et al 1966).

A patient with an osteogenic sarcoma has a very poor prognosis, and until 1972 survival rates ranged from 5 to 20 per cent (Jaffe 58, McKenna et al 1966, Dahlin & Wenger 1967, Marcove et al 1970), and this in spite of most aggressive and mutilating treatment procedures.

With the understanding of the phases of development of the primary tumor, micrometastases and overt metastatic disease,

and the introduction of systemic treatment by aggressive chemotherapy designed to shrink the primary tumor and treat the micrometastases, and with an aggressive approach to the metastases, major progress has been achieved in the treatment of these tumors (Jaffe et al 1974, Carter & Friedman 1978, Frei et al 1978).

In 1973 we performed our first total femur replacement for an osteogenic sarcoma (Katznelson & Nerubay 1976, 1977) and this paper reports our experience in five patients who were treated by femoral resection and replacement by a total femur endoprosthesis.

PATIENTS AND METHODS

Five patients with malignant tumors of the distal half of the femur were treated by total femur

Table 1 Clinical features of the patients

Patient	Age	Diagnosis	Time elapsing between onset of symptoms and operation	
1	13	Osteogenic sarcoma	5 months	Biopsy of
2	16	Osteogenic sarcoma	3 months	Biopsy
3	17	Osteogenic sarcoma	8 months	Biopsy
				Radiation
4	19	Chondro sarcoma	4 months	"
5	46	Chondromyxoid sarcoma	9 months	Two local

replacement at the Chaim Sheba Medical Center between 1973 and 1977. Three had osteogenic sarcomata, one chondro sarcoma and one chondromyxoid sarcoma. Their ages ranged from 13 to 46 years and all were males. Each patient was fully investigated: a physical examination, laboratory tests, standard x-rays including skeletal survey, chest radiological examination and bone scans were performed. One patient with an osteogenic sarcoma was treated preoperatively at another hospital (radiation for 6 months) and the patient with chondromyxoid sarcoma underwent two local resections prior to the total femoral replacement (Table 1).

The chemotherapeutic treatment has changed over the years. Our first patient in 1973 received high doses of methotrexate with citovorum factor, vincristine and adriamycin. Today the chemotherapeutic program is intraarterial adriamycin at the time of the preoperative arteriography (125 mg/day/2 days), followed 2 weeks after surgery with methotrexate (3-6

patient with standard hip the hip of the patient on an equal level.

The preparation and construction of thethesis takes 3 days.

SURGICAL TECHNIQUE

Initially a biopsy is performed, and Smith-Petersen approach to the hip joint

The endoprosthesis employed is of stainless steel having an Austin-Moore type head with a long stem to be inserted into the medullary canal of the tibia with a stabilizing platform that rests on the tibial plateau (Figure 1). The femoral stem is round at its proximal end and there are perforations to permit the reattachment of the trochanters. The tibial component of the stem is square in cross-section and tapering to its end. This square shaped stem prevents rotation of the tibia about the end of the prosthesis. The length of the stem and the position of the tibial platform is determined by orthoroentgenometry.

The size of the head of the prosthesis is determined by comparing the x-ray measurements of the head of the femur of the

Figure 1 Total femur prosthesis with a Moore head, a platform for stabilizing square tibial stem



Figure 2 Intraoperative picture showing the total femoral prosthesis in place

A skin incision is carried down laterally on the thigh with wide resection of the skin about the popliteal wound. A lateral arthrotomy of the knee with the incision proceeding down to the upper thigh is done.

The first step of the resection is to approach the knee joint, perform an osteotomy of the greater trochanter and retract it laterally with the gluteal muscles, also an osteotomy of the lesser trochanter is done with retraction of the psoas muscle. The hip capsule is then incised anteriorly and the femoral head dislocated. Arthrotomy of the knee joint is performed and all the tissues are universally divided, viz. the capsule, the collateral ligaments, the cruciate ligaments and the posterior capsule. This allows the distal femur to be raised and by careful blunt dissection the neuro-vascular elements of the popliteal fossa are displaced anteriorly and away from the femur.

At this stage Hunter's canal is identified and the femoral nerve, artery and vein are meticulously dissected along their full course from the upper thigh down to the popliteal fossa. All

- the femoral perforating and the geniculate arteries with their branches are ligated. The arteria profunda femoris is also divided.
- Then, having mobilized the neurovascular



Figure 3 Roentgenogram showing the total replacement of the femur by the prosthetic device



Figure 4 Full weight bearing on the operated limb

bundle the adductors are divided this then exposes the sciatic nerve in its fatty envelope and care is taken to ensure that it is not damaged.

The patella is maintained and division of the quadriceps tendon performed at its upper pole. The vastus lateralis is removed with the femur the fascia lata remaining behind.

The stem of the prosthesis is introduced into the medullary canal of the tibia and reduction of the



Figure 5 The range of abduction and adduction



Figure 6 The ability to actively flex the hip

of the prosthesis in the acetabulum is formed (Figure 2)

The capsule of the hip joint is repaired to give stability to the femoral head, the trochanters are fixed by wires in the holes in the prosthesis and the wound closed in layers over suction drains.

The average operation time is 3½ hours, ranging between 3 and 4½ hours, pre- intra- and postoperative prophylactic antibiotics are given (Figure 3)

RESULTS

The postoperative period of all patients was uneventful, and after 2 weeks the patients began to walk, first with the aid of a walker and thereafter with crutches, bearing full weight on the operated limb. After 3 weeks they walked with a cane and after 3 months no external support was necessary, except for the patient with chondromyxoid sarcoma who required constant external support. One patient developed a peroneal palsy which recovered after 4 months.

From a functional point of view, the results were excellent in four patients who achieved full weight-bearing, were free of pain and could walk for considerable distances (Figures 5 and 6). Apart from the inconvenience of a stiff straight knee they were able to return to their normal activities (Table 2).

Of these five patients three died, one 15 months following the replacement and the others after 2½ years, their deaths were attributed to the pulmonary metastasis in spite of resection of the metastases and chemotherapy. The patient with chondromyxoid sarcoma developed after 3 months a pulmonary metastasis that regressed with the chemotherapy, but he experienced severe pains in the knee region and his ability to walk decreased. A disarticulation of the hip was performed and a local recurrence in the upper third of the tibia was found. Our third patient with osteogenic sarcoma a year following the replacement developed pains in the knee region and x-rays showed a local recurrence in the popliteal fossa, and although an excision of the recurrence was done, the tumor recurred and a disarticulation of hip was performed.

DISCUSSION

This paper presents a different approach to the treatment of malignant tumors of the distal femur, the most common location of osteogenic sarcoma, and is based initially upon chemotherapy to shrink the primary tumor, followed by a radical resection of the tumor.

Table 2 Results of the total femur replacement

Patient	Diagnosis	Follow-up	Pulmonary metastasis	Complications	Functional results	Final results
1	Osteogenic sarcoma	15 months	Yes (resection)	~	Excellent	Died (15 months)
2	Osteogenic sarcoma	2½ years	Yes (resection)	~	Excellent	Died (2½ years)
3	Osteogenic sarcoma	2½ years	~	Local recurrence (excised)	Excellent	Hip disarticulation
4	Chondrosarcoma	2 years	~ (recovered)	Peroneal palsy	Excellent	Good
5	Chondromyxoid sarcoma	2 years	Yes (regressed with chemotherapy)	Local recurrence	Poor	Hip disarticulation Died (2½ years)

and total femoral replacement, as opposed to the "classical" amputation

The treatment was followed by systematic chemotherapy to combat the micrometastases which were not treated in the past, and if a metastasis was discovered, in place of the old palliative approach, we pursued an aggressive course with resection of pulmonary and local metastases, thereby prolonging the survival time

Different indications and techniques have been described Ottolenghi in 1966 replaced a whole femur by another femur in a patient with Echinococcus disease Buchman (1965) made the first prosthetic replacement of the whole femur for Paget's disease Sim et al (1978) report that at the Mayo Clinic amputation remains the treatment of choice in osteogenic sarcoma but with the recent advances in adjunctive treatment greater stress has been put on radical *en bloc* resection Of 15 patients having *en bloc* resection, two developed lesions in the distal femur and had a segmental total knee arthroplasty fitted, retaining the proximal femur After 6 months the patients are alive and well Marcove & Khafagy (1974) and Marcove et al (1977) have published reports on the use of a more sophisticated prosthesis However, from the reports we note that the prosthesis with a hinged knee had very poor functional results, and only one of their 19 patients had knee flexion of 90° They required a long rehabilitation period and the use of external support We believe that patients after the resection have little or very poor motor muscle power and are incapable of controlling a mobile knee prosthesis, whereas a stable and rigid knee facilitates a quick rehabilitation, gives a stable and pain-free gait, and is more beneficial to the patient

The surgical technique is easier with our prosthesis and a long operating time and all the risks entailed are avoided, Marcove reported an average operating time of 6½ hours for the fitting of a femur prosthesis with a hinged type knee, while our average operating time was half of this.

With our easy and speedily manufactured

prosthesis, there is no waiting time for surgery and the psychological shock to the patient and his family is prevented. The patient returns to his milieu within a week with "his full body image" maintained. Rehabilitation is good and rapid and psychological problems are prevented.

It is too early to suggest that this is the method of choice in the treatment of these highly malignant tumors, but as K (1978) signals "there are winds of change" the initial results are good, the limb is preserved and the psychological trauma of high level amputation is prevented. With further experience the results should be more promising.

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PROCEEDINGS OF THE NORWEGIAN ORTHOPAEDIC ASSOCIATION

TOR ARNT JAKOBSEN

October 25th-27th, 1979

EFFECT OF INSTABILITY ON EXPERIMENTAL

Regional Hospital, Bergen

A study the effect of varying stability on fracture healing, a bilateral tibio-fibular osteotomy was performed on nine Wistar rats weighing 350 g. Intramedullary nailing was performed with 14 mm stainless steel nails after reaming to a rigidity 40 kp/mm which corresponds to the rigidity of an intact tibia. The nails used in the right tibia had a middle part made of Ti-Ni and covered with PVC, giving the nail a high degree of flexibility (0.3 kp/mm).

After 8 weeks, eight out of nine flexible nails were fractured, the continuity being maintained by the PVC tube. All rats had hypertrophic callus on the right side, and scanty callus on the left side. There were no non-unions. The strength without fracture was greater on the right side ($P < 0.005$) (Ström 1193). There was no significant difference in rigidity. The ratio rigidity/strength was higher on the left side ($P < 0.01$).

The findings may indicate a qualitative difference in callus formation.

CHRONIC KNEE

Bakke A, Møller & A. Alho
Regional Hospital, Bergen

In a series of 156 patients admitted with acute meniscus defect of the knee without fracture or ligament instability 119 had a localized tenderness over the medial or lateral joint line, indicative of meniscal injury.

An arthrotomy confirmed the diagnosis in 106

cases. In two cases a rupture of the meniscus was found on the opposite side, in two there was a rupture of the anterior cruciate ligament and arthrotomy was unnecessary in four cases.

patients were treated expectantly. Arthroscopy was performed in 26 cases in the latter part of the series.

It is concluded that locking of the knee joint with localized tenderness over the joint line and

arthroscopy is necessary to prevent a fairly high frequency of unnecessary arthrotomies.

TREATMENT OF INFECTED NON-UNION

A. Alho

Regional Hospital, Bergen

The series consisted of three femoral and eight tibial infected non-unions, four of the latter with bone defect. Two femoral and seven tibial cases were immobilized with Hoffmann's external osteotaxis, the others with traction. Antibiotics were given systemically and by local irrigation-suction instituted during the surgical revision. In the femoral cases and in one tibial case the final osteosynthesis consisted of intramedullary nailing and cancellous bone grafting. Seven tibial cases were treated with external fixation combined with anterior tibial and posterolateral tibiofibular graft. When necessary the grafts were performed in two sessions, 2 to 6 weeks after the revision.

In all but one case the drainage ceased in the

course of 1 year from the beginning of the treatment, and 15 years from the time of the trauma. One tibial non union ended in amputation. The functional result was good in seven and satisfactory in two cases.

CAN RESUSCITATION MANOEUVRES AGGRAVATE CONCOMITANT NECK INJURY?

I A CLINICAL STUDY

Georg Blikra

Central Hospital in Akershus, Nordbyhagen

The effectiveness of establishing open airways by backward head tilt and the stable lateral position is well documented, but it has been claimed that a possible concomitant neck injury can be augmented.

A retrospective study of 150 patients with

clinically and radiologically, in only six patients was the lesion judged to be unstable for head tilt, and in only two of these had a period of apnoea or airway obstruction been present.

It is concluded that the risk of aggravating a cervical spinal cord injury in an unconscious patient by backward head tilt to open the airways is very small, and when this procedure is indicated it should be performed without delay.

CAN RESUSCITATION MANOEUVRES AGGRAVATE CONCOMITANT NECK INJURY?

II AN EXPERIMENTAL STUDY

Georg Blikra, Knut Bøgseth & Nils Magnus Ulrik

Central Hospital in Akershus, Nordbyhagen

In an experimental model, artificially inflicted lesions to the neck, simulating those most commonly seen in clinical cases, were produced in autopsy cases. The cervical spines were studied radiologically, simultaneously with the performance of common first aid measures to open airways and establish a stable lateral position.

In these experimentally produced unstable flexion-type injuries at the levels C4/C5, C5/C6 and C6/C7 no significant deformation of the spinal canal during backward tilt of the head could be demonstrated. In establishing a stable lateral

position some lateral flexion and deformity in extremely unstable spine could be observed during the turning. Extension deformation of the spinal canal was not seen. The support method used during the turning proved to be the best one.

FRACTURES OF THE UPPER END OF THE FEMUR IN OSLO

AN EPIDEMIOLOGICAL STUDY

J. Falch & U. Shungard

Aker Hospital, Oslo

The records for all patients admitted to hospitals in Oslo in the year 1971 with fracture proximal to the lesser trochanter were studied.

The total number was 1100, 849 females and 251 males. The age and the sex specific incidence increased exponentially for both sexes, and for the oldest age group (80 years and over) the incidence was 1.4 per cent for males and 1.1 per cent for females. Thus the incidence the risk for a 30-year-old person suffering an upper femoral fracture before the age of 80 years will be 1/6 and for a 70-year-old person 1/6. Compared with other countries the incidence reported is surprisingly high.

Twenty-one per cent of the females and 14 per cent of the males were younger than 40 years. Among other diseases recorded were, for females and males, respectively: previous fracture of the upper end of the femur 14 and 6 per cent, alcoholism 2 and 12 per cent, and previous trauma 4 and 10 per cent.

CONGENITAL PSEUDARTHROSIS OF THE CLAVICLE

Rolf Hagen

Marina Hansen Hospital, Sandvika

Congenital pseudarthrosis of the clavicle is a rare malformation which almost always involves the right side. The aetiology is unknown, but Lloyd-Roberts et al. (1970) have suggested that the condition is due to the pressure exerted by the subclavian artery on the developing clavicle.

A 7-year-old girl with this malformation, with no history of obstetric complications, no cervical ribs or unduly thickened ribs, no neurofibromatosis, dysostosis cleidocranialis or other familial implications, is presented. She underwent resection of the clavicle.

plantation of cortico-cancellous bone from iliac crest and fixation with a Kirschner wire. Right-sided non-union healed completely in 4 1/2.

TURES OF THE SUPRASPINATUS DON REPAIRED THROUGH A TEROSUPERIOR TRANSACROMIAL ROACH

r Dregelid

onal Hospital in Tromsø, Tromsø

our patients with rotator cuff ruptures were
aled on using a postero-superior
acromial approach *ad modum* DeBeyre et al.
Bone Jt Surg 1965 47 B, 36-42). The
nique was slightly modified by using a screw
osteosynthesis of the acromion. In two of the
mis the trapezius attachment on the spina
sculae was osteotomized, and in closing the
nd was sutured back by osteosutures. The
roach provides sufficient access to the rotator
thus making repair easy, and also permits
utilization of the supraspinatus muscle in long-
ding cases where retraction of the tendon is
id.

E PIRIFORMIS SYNDROME

ing Fjeld Solheim & Per Siemsen
uma Hansens Hospital, Sandvika

The piriformis syndrome is characterized by
back pain and hip pain with sciatic radiation.
male patients usually complain of dyspareunia.
radiological signs are absent. Pain and weakness
rusted abduction-external rotation of the
th and tenderness over the belly of the
formis muscle are typical signs.
Five women treated with section of the
formis muscle were reported. The average time
follow-up was 7 months. The result was rated
good in one patient and as fair in one. In the
rd patient, who had a generalized pelvic floor
alza, the operation had no effect.

PLICATION AFTER LUMBAR MINECTOMY

ell Harbo

ntial Hospital in Rogaland, Department
ndnes, Sandnes

A 55-year-old man was operated on because of
spinal stenosis and had the lamina and the joint

pedicles of the two lowest lumbar vertebrae
removed. Half a year later while driving his car
was hit violently from behind. Radiological ex-
amination revealed a 10 mm spondylolisthesis
between L 5 and S 1. The patient was later
operated on and treated by anterior fusion.

It is concluded that removal of the joint pedicles
leaves the lumbar spine with reduced stability and
this procedure should be omitted.

LOOSENING OF THE FEMORAL COMPO- NENT IN HIP ARTHROPLASTIES

d Alho, O Sorride, K Heidtten & J Lillenes
Regional Hospital, Bergen

Clinical and radiological data were examined for
318 patients who had received various hemi-endo-
and total hip prostheses. The data were classified
into general, structural and loosening variables.
Analysis for multiple qualitative data gave highly
significant mutual correlations between medial and
axial drift of the shaft, radiolucent zone between
bone and cement, lateral cortical thickening,
resorption of the calcar and cement fracture. The
lack of direct correlation between resorption of the
calcar and radiolucent zone may indicate that
these signs represent different aspects of loosening.
Varus position of the femoral component
predisposed to medial and axial drift and cement
fracture.

The radiological criteria of loosening vary in
clinical importance, and the need for reoperation
has to be judged individually.

OSTEOARTHRITIS OF THE HIP TREATED BY INTERTROCHANTERIC OSTEOTOMY

A Ringstad & T Grønmark

Krøppemasse Martha's Institute, Oslo

A follow-up study of 103 intertrochanteric os-
teotomies in patients with osteoarthritis of the hip
was reported. Two-thirds were women. The mean
age was 53 years. Half of the patients were over
60 years of age. The degree of radiographic
osteoarthritis according to Kellgren & Lawrence
was Degree I (severe) = one-fourth, degree II =
one-half and degree III = one-fourth.

One year postoperatively 71 per cent of the
patients still reported that the operation had had a
good effect, and 11 per cent reported some effect.
Seven years postoperatively these figures were
reduced to 45 per cent and 6 per cent.

respectively. At this time 24 per cent of the patients had required a total hip replacement and 7 per cent an arthrodesis of the same hip.

The clinical results after osteotomy were independent of the age of the patients and of the preoperatively recorded radiographic degree of the osteoarthritis.

BIOMECHANICAL STABILITY OF FEMORAL NECK OSTEOTOMIES FIXED BY THORNTON'S SIMPLE NAIL BY McLAUGHLIN'S NAIL AND PLATE, AND BY THE HIP COMPRESSION SCREW

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Ullevål Hospital Oslo

The bending and rotational stability of experimental cadaveric femoral neck osteotomies fixed by Thornton's triflanged nail, McLaughlin's nail and plate and the Ullevål hip compression screw were reported. The bending stability of the three tested devices was statistically equal whereas the rotational stability of the Thornton nail was lower. The rotational stability, however, of all three tested devices is sufficient under normal clinical circumstances. The bending stability achieved by the three devices on the other hand is insufficient to counteract the forces acting upon the femoral head *in vivo*, and is the most obvious reason for the high rate of non-union in femoral neck fractures.

CLINICAL EXPERIENCES WITH FEMORAL NECK FRACTURES TREATED BY THORNTON'S NAIL CEMENTED IN METHYL METHACRYLATE

A. Reigstad
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Thirteen patients with dislocated subcapital femoral neck fractures of Garden types III and IV, and one patient with a one year old non-union of the femoral neck were treated by a cemented nail. After reduction of the fracture cancellous bone from the head, the neck and from the greater trochanter was partly removed by means of a round cutting burr introduced through a small hole in the lateral trochanter area. The cavity was filled up with methyl methacrylate cement using a cement syringe and a Thornton nail was then introduced through the cement.

The patients were allowed immediate weight bearing postoperatively. One patient died after surgery. The remaining patients followed up for 2 to 8 months. No redislocations occurred and the clinical results so far are good.

CARCINOMA IN CHRONIC OSTEOMYELITIS

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Martina Hansens Hospital, Sandvika

A case of squamous cell carcinoma in an old man arising in the sinus tract of a chronic osteomyelitis in the lower leg of 14 years duration was reported. The tumor was uncommon and chiefly seen in middle age with fistulating chronic osteomyelitis in the extremities. Malignant degeneration is suspected when there occurs a characteristic clinical pattern in cases of chronic osteomyelitis. Biopsy should include tissue from the bone and lymph nodes. The prognosis is poor when early adequate amputation is performed.

Oslo, November 17th, 1979

CONGENITAL HYPOPLASIA OF THE TIBIA

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Kristiansand

One case of congenital hypoplasia of the tibia with intrauterine fracture and arthrogryposis. At birth anterior bowing and angulation were present. The fracture site was already healed. The tibia was already replaced by a glass shaped tibia. A bridge of newly formed bone on the medial side of the defect. The fibula was normal in size and displaced proximally.

The child was operated upon at the age of 18 months. From the upper fibula a cement nail was extraperitoneally and a femoral leg was extraperitoneally. The bowed tibia diaphysis was resected and replaced after being turned 180 degrees. The nail was threaded on a Kirschner wire and inserted into the tibia diaphysis (a Kirschner procedure).

The tibia healed after 6 weeks. The child was able to walk at the age of 20 months. The joint was in a good position and the child was in a lively way although the leg is still short. The prognosis seems to be good.

ness of the leg which will require a lengthening-ostheostomy. According to Skou Andersen's and Robert's classifications this case does not present a true congenital pseudarthrosis

GENITAL ANKYLOSIS OF ELBOW

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Kristiansand

Congenital ankylosis of the elbow is an extremely rare condition. Of the 35 cases published, however, 7 bilateral ones have been reported in Norway. The condition may be encountered in two groups: 1) As an isolated, usually unilateral deformity; 2) In association with other anomalies.

In this case, a boy, was reported who fits into the first category. He has a left-sided humeroradial ankylosis combined with a deformity of the upper humeral epiphysis and the upper end of the ulna is smaller than on the other side. At the age of 17 months the elbow angle was 50°, and the forearm 5 cm shorter and the forearm 1 cm shorter on the other side.

The boy can easily put his left thumb into his mouth and is able to use his deformed arm and hand very well. In this unilateral case, therefore, there is no indication for surgery.

TREATMENT OF BONE INFECTION WITH IMPLANTATION OF TETRACYCLIN POLYMER BEADS

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Kristiansand

Two cases of infected tibial fractures were treated unsuccessfully for several months medically with cloxacillin and lincomycin. Nine to two years after the injury gentamycin and tetracycline beads were implanted into the tibial shaft in one case and into the condyles of the tibia in the other case. In both cases the infection disappeared in a few weeks, the wounds closed and the fractures consolidated. There were no signs of recurrence of the infection after 1½ years.

Oslo, December 15th, 1979

VERTEBRAL HAEMANGIOMA

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Haemangioma in bone is a centrally growing vascular malformation which accounts for 1 per cent of all primary osseous malformations. Radiological examination usually reveals characteristic changes but these can occasionally be atypical.

A female who in 1969 underwent a radical mastectomy for cancer of the breast, had a radiological examination of her spine performed in 1973 because of back pain. Changes in the third lumbar vertebra suspiciously like a metastasis were found. Medication with corticosteroids and cytostatics was instituted, but her back pain increased, and so did the osseous destruction.

In 1979 sciatica and bladder paralysis suddenly developed. A laminectomy was performed and a haemangioma in the third lumbar vertebra was found. Postoperatively the pain disappeared immediately and bladder function returned to normal.

It is concluded that even though the radiological changes are characteristic of a solitary metastasis in bone, a haemangioma should be considered in the differential diagnosis.

OPERATIVE TREATMENT OF NEGLECTED MONTEGGIA FRACTURES IN CHILDREN

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Three children 5, 7 and 9 years old, respectively, with neglected Monteggia fractures were operated upon 7 weeks to 8 months after injury. In all cases the capitulum of the radius was reduced, and in two cases a new annular ligament was reconstructed using a lateral strip of the triceps tendon. In the third case the capitulum had merely slipped out of the unruptured ligament which could be used for reconstruction. In all cases the reduction was secured temporarily with the aid of a Kirschner wire inserted through the capitulum humeri into the proximal part of the radius.

The results so far are promising.

ANTERIOR INTERBODY FUSION OF THE LUMBAR SPINE

Tor Steinar Raugstad

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In the period 1973 to 1977, 48 patients with incapacitating low-back pain caused by disc degeneration or spondylolisthesis were treated with anterior interbody fusion by the extraperitoneal technique. The mean age at operation was 38.4 years.

Thirty-three of these patients (17 with disc degeneration and 16 with spondylolisthesis) were followed up an average of 48 months postoperatively. Patients' own opinion: 15 patients (45 per cent) had no complaints, 12 (36 per cent) were improved, 5 (15 per cent) were unchanged, and one (3 per cent) was worse.

Thirty-three discs in 31 patients were examined radiologically, and in 28 (85 per cent) the fusion was solid. Probable pseudarthrosis occurred in four patients operated for spondylolisthesis and in one for disc degeneration. Out of these five patients two had no complaints, two were improved and one was worse than before operation. Full working capacity was found in 25 patients (76 per cent).

PROXIMAL TIBIAL OSTEOTOMY FOR GONARTHROSIS

Arvid Høegberg

Central Hospital in Rogaland, Department Sandnes, Sandnes

A series of 34 patients with gonarthrosis treated by proximal tibial osteotomy was presented

Preoperatively 31 of the patients had at least three a valgus deformity.

At a 2-year follow-up examination 11 were relieved of the pain, two were not and two were worse. Mobility was not affected by the operation. There were no serious complications, but one patient lost the ability to dorsiflex the great toe, and three presented minor sensibility disturbances on the dorsum of the foot.

EARLY TREATMENT OF SPINAL INJURIES WITH CORD LESIONS

Oddvar Anda

Central Hospital in Rogaland, Department Sandnes, Sandnes

Correct early treatment of cord lesions is necessary to avoid later serious complications. Pressure sore prophylaxis by turning the patient every second hour is started immediately. Physiotherapy with breathing exercises, passive joint movements which prevent contractures and reduce spasm.

Urinary tract complications are prevented by using an indwelling catheter the first week, followed by intermittent catheterization and bladder training.

Operative treatment of a spinal cord lesion is necessary in the acute phase.

ANTIBIOTIC CONTAINING BONE CEMENT BEADS IN THE TREATMENT OF DEEP MUSCLE AND SKELETAL INFECTIONS

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JÖNSTEN TÖRHOLM & ROLF ÖNNERFALT

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Forty-eight cases of chronic osteomyelitis or bacterial arthritis operated on with eradication of infectious lesions were randomly treated either by insertion of suction-irrigation drainage or by implantation of gentamicin beads. The average follow-up time was 2 years.

There was no difference in the recurrence rate between the two groups. The gentamicin treated patients were however more easily cared for as the suction-

Keywords: bone cements, drainage, gentamicin, osteomyelitis

Accepted 5 v 80

During the past decade antibiotic containing bone cements have been successfully used both as a prophylaxis against infections in operations with joint replacements (Buchholz & Garton 1972, Garton et al 1973, Buchholz et al 1977) and as a means of eradicating an established infection in revision infected total hip arthroplasties (Buchholz et al 1977, Carlsson et al 1978). The cement has been shown to release antibiotics in such quantities *in vitro* and *in vivo* that the local concentrations exceeded the MIC values of most bacteria considered capable of causing skeletal infection (Wahlgren et al 1972, Gardner Medcraft 1974, Picknell et al 1977, Wahlgren & Dinkelmann 1978). Of the various types of bone cement now available Palacos® has proved to be the most effective in releasing antibiotics (Garton et al 1973, Lindberg 1979).

On the basis of their experience in revisions of infected total hip arthroplasties, Voorhoeve & Stöhr (1973) treated 17 patients with chronic osteomyelitis by insertion of a gentamicin-polymethylmethacrylate plug. However, during an observation period of 20 months, five recurrences occurred. In order to increase the release of antibiotics, which occurs in proportion to the surface dimensions of the cement, Klemm (1976) introduced an antibiotic bone cement mixture in bead shape. The separate beads were left in place in the first cases operated upon but the technique was later modified so that 30 antibiotic beads were threaded on a twisted stainless steel string which permitted easy extraction. These antibiotic beads (Septopal, Merck, West Germany) have been used principally in deep subacute or acute soft tissue and skeletal infections (Klemm 1976).

The aim of the present study was to compare conventional treatment using suction irrigation drainage with treatment by implantation of antibiotic bone cement beads in a series of patients with severe chronic osteomyelitis and bacterial arthritis.

MATERIAL

This study comprised 47 patients with 48 cases of chronic osteomyelitis or bacterial arthritis. All of them would otherwise have been treated with radical eradication of the infected tissue and insertion of a closed suction irrigation drainage (Willenegger & Roth 1962). The indications for operation were an active secreting fistula or severe pain at rest or repeated exacerbations. The series consisted of 32 men and 15 women aged 12–80 years with a mean age of 49 years.

The infection was hematogenous in five cases and post traumatic after open fractures in six cases where no primary operations had been performed. Thirty seven were postoperative infections of which 33 had had foreign material implanted.

The average duration of the disease was 10 years (range 1–64 years). In 11 patients the disease had been present for more than 10 years.

The location of the infections is shown in Figure 1. Fourteen were located in a joint, the remaining 34 in the skeleton.

In a prospective study it was decided at random whether the patients would be treated with gentamicin beads or by suction irrigation drainage. Chronic osteomyelitis and bacterial arthritis were equally distributed in the two groups. All of the patients had normal kidney function before operation.

BACTERIOLOGY

The bacteriologic cultures were classified as positive only if repeated samples taken from fistulas on several occasions showed growth of the same bacteria or if more than three out of five cultures taken during operation from various sites in the operation area showed identical bacteria (Lidgen et al. 1978). Deep biopsy cultures were taken from the infected tissue. If foreign material was present, the biopsies were taken from the adjacent tissue. To avoid contamination each piece of tissue was taken with a separate sterile forceps, put into a separate CO₂ tube and im-

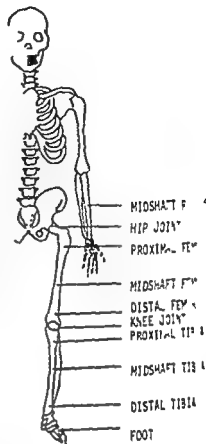


Figure 1 The localization in 43 cases of osteomyelitis

mediately taken to the bacteriology for both anaerobic and aerobic cultures. The results are shown in Table 1. The most bacteria found was *Staphylococcus aureus*.

Table 1 Results of bacteriological cultures in cases of chronic osteomyelitis

<i>Staphylococcus aureus</i>
<i>Staphylococcus epidermidis</i>
α -streptococci
β -streptococci
<i>Streptococcus faecalis</i>
<i>Escherichia coli</i>
<i>Pseudomonas pyocyanus</i>
Anaerobic streptococci
Aerobic mixed infection
Anaerobic + aerobic mixed infection
Negative culture

n out of 46 positive cultures showed growth
Pseudomonas pyocyanea

METHODS

Eight operations were performed on 47
nts, 23 of whom were treated with
amycin beads and 25 by conventional
ods. A complete eradication of the infectious
n was aimed at in all cases.

1 patients received systemic antibiotics after
culture specimens were taken. Thus antibiotic
ment was continued for an average of 7
ths postoperatively. Seven cases from each
are currently undergoing treatment.

1 some cases the treatment deviated in
iple and will therefore be discussed further.
medullary reaming was performed in 14 cases
rder to revitalize and revascularize the bone
ugh improvement of the endosteal circulation
gren & Torholm 1980). In one case an
mal fixation was carried out with a Küntscher
and in one with a Zickel nail. In seven cases
nal fixation according to Vidal Adrey was
l. In five cases of bacterial arthritis partial
nectomy was performed, four in the knee joint
one in the hip, in the latter case resection of
femoral head was also carried out. The foreign
erial was usually extracted but in cases of
aled fractures the fixation was retained until
fracture was healed.

o evaluate the extent of devitalized tissue in-
ital staining with Disulphine Blue (ICI Great
ain) was used in nine cases (Klemm 1976).
s also facilitated the extirpation of all granula-
tissue and sequestra. Disulphine Blue was
n intravenously for 10 minutes in the
ating theatre by the anesthesiologist 1 hour
re operation. The Disulphine Blue dis-
ared within 2 to 3 days. No side-effects were
rved.

he antibiotic beads used were 7 mm in
eter and had a weight of 0.2 grams. Each
d contained 7.5 mg gentamicin corresponding
5 mg of gentamicin sulphate.

he beads were inserted into bone as well as
soft tissues. The remaining cavities were
d at operation with beads, the number varying
n eight (36.0 mg gentamicin base) to 540 (2430
gentamicin base). The beads were left in
ation, usually with one bead outside the skin to
itate removal which was done after 2 weeks
ge 8–29 days) without the use of anaesthetics.
ree of the cases were operated on more than
e and when the beads were removed a
nsplantation of cancellous bone was carried out.
asurement of the gentamicin concentration in

the serum, urine and blood was carried out in nine
cases.

The average treatment time with closed

acetated Ringer's solution at body temperature and
without antibiotic additive was heated in a blood
warming vessel and circulated continually
throughout the operation area.

RESULTS

All patients were re-examined on average 24
months postoperatively (range 9–39 months).
Two recurrences were noted in the group
with gentamicin beads. One case had had an
open fistula for more than 33 years and a
poor condition of the skin in the lower leg.
An attempt to move a skin flap was un-
successful, the wound split open, and the
fistulae recurred, however, after 9 months it
was still free from the original strain of
Pseudomonas pyocyanea. The other patient
had a small persistent fistula which produced
a drop or two of pus daily.

Four recurrences were noted in the group
treated by suction-irrigation drainage. Two
abscesses needed incision, one after 1 month,
the other after 7 months. The original
bacterial strain was cultured in both cases. In
another patient the pain continued and a new
fistula developed after 9 months. The fourth
patient retained his fistula during the entire
postoperative period, but the condition was
painless. No significant difference between
the two groups was found concerning the
recurrence of the infection ($P > 0.05$, Chi-
square test).

Some difficulty was encountered in
comparing the two groups in terms of the
time spent in hospital and in bed, because of
other injuries and seven patients were not
included in this calculation. The average
length of time spent in hospital in the group
treated with suction-irrigation drainage was
22 days of which 5 were spent in bed. The
figures for the gentamicin group were 27 and
3 days, respectively.



Figure 2 Gentamicin concentrations in serum, wound secretion and urine after implantation of gentamicin - polymethylmethacrylate beads (mean 140 beads, range 18-540) in nine patients with chronic osteomyelitis

Gentamicin concentrations were determined by Kahlmeter, Department of Medical Microbiology, Lund, Sweden, using a previously described agar well diffusion technique (Kahlmeter et al 1978)

Twenty-two of the patients had unhealed fractures and chronic osteomyelitis. These fractures were all healed at re-examination. The gentamicin concentration in the wound secretion, blood and urine for the nine patients examined is shown in Figure 2

Case report 1

An 18-year-old girl with a closed femoral fracture and a comminuted fracture of the tibial plateau. The patient was operated upon after 2 weeks with open reduction and fixation of the fracture of the tibial plateau by a screw and of the femoral fracture by a Kuntscher nail after intramedullary reaming. Postoperatively the patient developed a hematoma, which was evacuated. After this a severe infection developed with growth of *Staphylococcus aureus*. In spite of treatment with antibiotics (cloxacillin, gentamicin, lincomycin in high doses), the patient's septic condition continued. On radiographic examination gas was noted in the soft tissues surrounding the femoral fracture. The patient was reoperated upon and an abscess was found communicating with the

fracture. Preoperative cultures growth. After débridement, 60 were inserted (Figure 3a). The patient treated with lincomycin parenterally rapidly. After 3 weeks there was infection and the beads of which outside the skin were extracted (Figure 3b).

Case report 2

A 34-year-old man with an infected fracture after primary fixation with a



Figure 3a Radiographic examination of gentamicin beads inserted into the femoral fracture

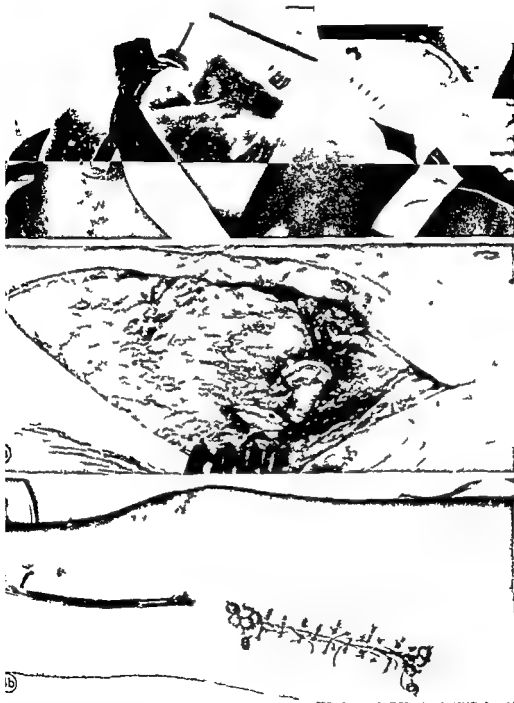


Figure 3b The green colouring of a patient shown 1 hour after intravital staining with D sulphine Blue

Figure 4a The operating area is shown with a clearly visible white sequestrum

Figure 4b A couple of beads should be left outside the skin to facilitate extraction.

The plate had been removed after 5 months. The patient was treated with a plaster cast but a fracture occurred.

(Figure 4) An accumulation of infected soft tissue and necrotic bone (Figure 4a) and subsequent insertion of 18 gentamicin beads. The fracture was stabilized with the Vidal-Adrey apparatus. Transplantation of cancellous bone was carried out 4 weeks later and the patient was allowed to gradually take weight on the affected leg. The external fixation was abandoned after 3 months. The patient was given a below knee brace (Sarmiento 1970) for an additional 3 months and he was allowed full weight-bearing. Eight months after the bone transplantation the fracture was united.

DISCUSSION

Successful treatment with gentamicin beads in deep acute and subchronic infections of bone and soft tissue has been reported by Klemm (1976) and Jenny et al (1977). The observation period in the present study was 24 months, too short a time to judge the healing results in chronic osteomyelitis, but there was no difference in the recurrence rate between our groups. There was no decrease in the time spent in the hospital but the patients treated with gentamicin beads spent about 2 days less in bed. The main advantage was that these patients were more easily cared for as the suction-irrigation drainage required constant attention and often caused difficulties (Asche 1978).

The majority of the infections in this study were caused by *Staphylococcus aureus* but in no less than 16 per cent (7/48) the responsible organism was *Pseudomonas pyocyanea*. Systemic treatment with toxic preparations could be avoided and concentration determinations in nine of the patients showed no measurable levels of gentamicin in the blood. This is in agreement with other reports (Wahlig et al 1972, Wahlig & Dingeldein 1978). On the other hand, an accumulation of gentamicin could admittedly occur in the kidneys, since a significant quantity of gentamicin is excreted in the urine. A rapid

release *in vitro* as well as *in vivo* has been shown with a certain delay in the case (Picknell et al 1977). There is a reason to leave the gentamicin beads in place for more than about 2 weeks, considering the release of antibiotics found in this situation, particularly during the first 2 weeks. Moreover, the extraction of the beads become difficult after more than 2 weeks because fibrous tissue grows in between the beads. Gentamicin is most effective against gram-negative infections especially those caused by *Pseudomonas pyocyanea* but is also effective against *Staphylococcus aureus* infections and probably against some anaerobic bacteria in the concentrations which are obtained from the beads. Development of resistance against gentamicin during treatment was noted in this situation. There is reason however to limit treatment only against the infection at the local treatment. Experiments with gentamicin added to bone cement show promising results (Voorhoeve & Stor 1973, Leys & Picknell et al 1977, Lindberg 1979).

Temporary treatment with gentamicin beads should thus be confined principally to cases of deep gram-negative skeletal infections where it is necessary to apply general treatment with toxic preparations. Tensionless wound closure is a prerequisite for this method. If a large cavity remains, this can be filled with cancellous bone or muscle.

ACKNOWLEDGEMENT

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THE CONTACT AREA AND PRESSURE DISTRIBUTION PATTERN OF THE KNEE

Study of Normal and Osteoarthrotic Knee Joints

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Seven knees were studied to determine the contact area and pressure distribu-

without menisci, and the menisci occupied 70 per cent of the total contact area.

intact knee and the contact pressure considerably increased. These facts imply that the menisci have load bearing and load spreading functions.

The contact areas were also measured in two osteoarthrotic knees and they were significantly larger than those in normal knees. In these arthrotic knees the menisci seemed to play a less significant role in transmission of weight than in the normal knees.

Key words: contact area, knee joint, meniscus, pressure distribution

Accepted 10 v 80

menisci have often been considered worthless if a meniscal tear has been an indication for complete meniscectomy. But after Fairbank's report (Fairbank 1948) it was recognized that the menisci have several important functions. Swenson & MacErlay (1941) proposed six mechanical functions of the menisci. Recently Tapper & Hoover (1969), Appel (1970), Johnson et al. (1974) and Kurosawa et al. (1976) separately reported long term follow-up studies after meniscectomies. Johnson et al. noted a higher incidence of degenerative articular changes in meniscectomy cases. At the same time he emphasized the necessity of studying the physiological and biomechanical functions of the menisci.

To clarify the function of the menisci in

detail and examine the load transmitting pattern of the tibiofemoral joints in normal and osteoarthrotic knees, we performed the present experiment.

MATERIALS

Seven freshly amputated knees were used. The specimens were frozen at -20°C and they were thawed gradually at room temperature when used. The amputations had been performed because of vascular insufficiency in four cases, malignant tumour in two and osteomyelitis in one. Age distribution was from 41 to 80 years. Mild degenerative changes (articular surfaces were thin and markedly fibrillated) were noted in knee no. 3 and severe changes (articular surfaces of both tibia

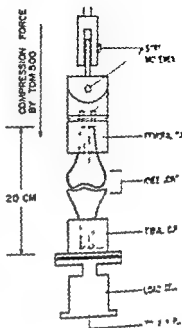
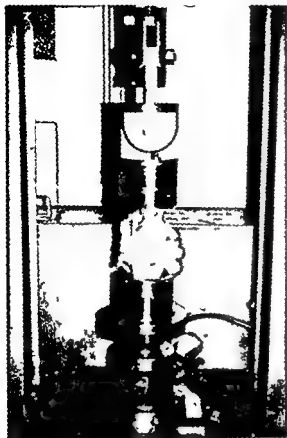


Figure 1 On the left a knee specimen fixed to the special device. On the right its structure. One of three joints on this device the knee specimen can be placed in any desired position.

and femur were totally eburnated) were seen in knee no. 4. The others were considered to be normal.

METHODS

The specimens were cut about 10 cm above and below the joint line. The patellae and muscles were removed, but the ligaments and capsules were left intact until the specimen was in place on the special fixation device (Figure 1). The device which has three linked joints can provide 0°, 30°, 60° and 90° of flexion, and the required varus-valgus angulation and rotation of the knee. After reaming the femoral and tibial medullary canals, the knee specimens were fixed to the fixation device using bone cement. The tibial component of the device was clamped to the load cell, and the femoral component was attached to the cross-head of an Instron type loading machine (TOM 500 made by Shinko Co., Ltd. Tokyo). In this study the knee specimens were tested at 0° flexion. The tibia stood perpendicular to the floor and

physiological valgus and internal rotation of the femur were chosen. Once the knee position was obtained, the pressure was changed throughout the experiment. One of the fixation devices had been used. The ligaments and capsules of the knee were severed. The medial collateral ligament was carefully cut at their femoral origins and the meniscotibial ligaments intact.

For direct measurement of pressure patterns (knees nos. 5, 6 and 7) we used thin, flexible and sensitive microcapsules by Fuji Film Co., Ltd., Tokyo, which consist of two polyester films. With microcapsules of two polyester films. With microcapsules contained in the film, the dye stuffs of the capsules come out with the colour-development process, a red colour to appear. By measuring the intensity of the redness using a densitometer, the pressures could be obtained with an accuracy of 10 per cent.

To measure the pressure on the tibiofemoral joints, the knee joint was employed using a silicone rubber film by Bayer Co., Ltd., Leverkusen, Germany.

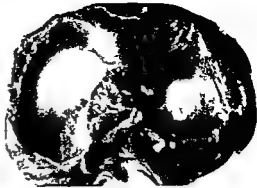


Fig. 2 Castings with (left row) and without (right row) menisci. Note the obvious boundary of the contact area and the boundary lines between the menisci and the uncovered cartilage.

commonly used as dental impression material*. To obtain the momentary deformation and the contact area, the stress-relaxation method was chosen as a loading procedure. The specimens were loaded to the set peak load at 10 mm/min deformation rate and then the cross-head of the loading machine was stopped in order to avoid creep deformation. In comparison with other loading procedures, this method was able to define a precise contact area which resembled closely the momentary contact pattern.

For knees nos. 2, 3, 4, 5 and 7, the castings were taken before and after the removal of the menisci under loads of 200 N, 500 N and 1000 N. For knee no. 1 the castings were taken only after removal of the menisci. From these castings we could easily measure the contact area of the menisci and the exposed cartilage separately using section papers and a planimeter. In knees nos. 5, 6 and 7 the pressure distribution patterns were also measured.

RESULTS

Areas of contact

i Contact area before and after the removal of the menisci Figure 2 shows the castings before and after the removal of the menisci. The contact area increased as the load increased, but the increasing curve was convex and the rate of enlargement of the contact area gradually reduced (Figure 3). So the average contact stress increased as the applied load increased. Table 1 shows the mean values and standard errors of the contact areas of the normal knee joints. The contact area of the knee joint before the removal of the menisci was more than twice as large as that after the removal of the menisci. When comparing the medial contact area with the lateral one, the former always occupied a larger area than the latter, but as the load increased, the difference between them gradually decreased. This meant that the load distribution to the medial and tibial plateau was

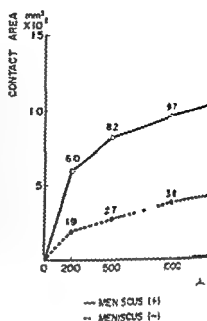


Figure 3. Contact area vs. load for knee flexion.

gradually balanced as the applied load increased.

ii Contact area on the menisci and the unloaded part of the cartilage When load was applied, areas of contact were both on the menisci and on the unloaded part of the cartilage. Figure 4 shows the contact area of the menisci compared with the total contact area in each compartment. Under low load, the contact was almost on the menisci alone (especially in the medial compartment). Even when the 1000 N load was applied, about 70 per cent of the contact area was on the menisci. It was said that the menisci play an important role in widening the tibio-femoral contact area.

iii Contact area of the degenerated knees compared with the normal knees Figures 5a and 5b show the load contact areas of degenerated knees compared with normal knees. The former had larger contact areas than the latter both before and after removal of the menisci. The degenerated knee (no. 4) had a considerably larger contact area than the normal knee

*The physical properties of the material were as follows: Maximum mixing time 1 min. Minimum working time 4 min. Maximum permanent deformation 2 per cent. This material could reproduce a line 0.025 mm wide.

Table 1 Mean values and standard errors of the contact areas of normal knees

Before the Removal of Menisci

Applied load	200N		500N		1000N	
	$\times 10^2 \text{ mm}^2$	%	$\times 10^2 \text{ mm}^2$	%	$\times 10^2 \text{ mm}^2$	%
Medial side	4.2 ± 1.5	(42)	5.3 ± 1.5	(54)	6.4 ± 1.8	(64)
Lateral side	2.7 ± 0.5	(30)	4.2 ± 0.6	(48)	5.1 ± 0.7	(58)
Total	6.9 ± 1.5	(37)	9.6 ± 1.7	(51)	11.5 ± 2.0	(62)

After the Removal of Menisci

Applied load	200N		500N		1000N	
	$\times 10^2 \text{ mm}^2$	%	$\times 10^2 \text{ mm}^2$	%	$\times 10^2 \text{ mm}^2$	%
Medial side	2.0 ± 0.8	(19)	2.4 ± 0.8	(22)	3.0 ± 0.8	(29)
Lateral side	0.7 ± 0.2	(7)	1.6 ± 0.5	(17)	2.3 ± 0.8	(24)
Total	2.5 ± 0.9	(13)	3.8 ± 1.1	(19)	5.2 ± 1.3	(26)

() percentage of the contact area to the respective tibial articular surface

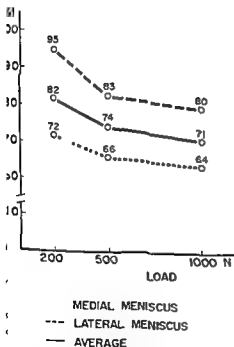


Fig. 4 Percentage contact area of the menisci compared with the total contact area. Note the percentage of the lateral side is higher than the medial side.

degenerative changes (no 3). The decrease in the size of the contact area after the removal of the menisci was less than that in the normal knees; this was especially noticeable in the severely degenerated knee.

Pressure distribution patterns

By using the special pressure sheet, we measured the pressure across the tibiofemoral joint directly. Thus by using the casting method and sensor sheet method the load distribution pattern could be obtained. Figure 6 depicts the patterns of knees nos 5, 6 and 7. At 1000N load the peak pressures of the medial and lateral sides of the knees were about 2–3 MPa, and at 1500N load they reached about 3–4 MPa. After the removal of the menisci the pressure increased and reached about 6 MPa, though the contact areas decreased to half that of the intact knee, and the points of peak pressure were within the same area of contact. In the medial compartment the high pressure areas were on the uncovered cartilage, but in the lateral compartment they were on the lateral meniscus as well as on the uncovered cartilage. To

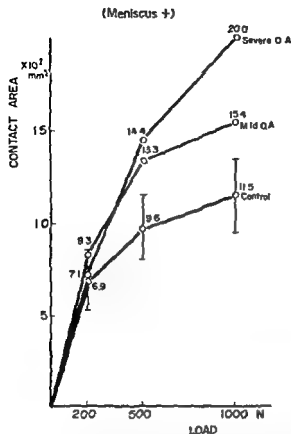


Figure 5a Contact area vs load for degenerated knees with menisci. Note the degenerated knees have larger contact areas than the normal knees

examine the accuracy of these pressure distribution patterns, we integrated the pressure values and the casting areas in knees nos. 5 and 7. The difference between the actual load and the force calculated from the pressure patterns was within 20 per cent.

DISCUSSION

1 Comparison with recent papers

There have been several reports on the contact area of the knee. Hettelkamp & Jacobs (1972) demonstrated the tibiofemoral contact area under a 30–80 N load by roentgenographic methods. The contact area after the removal of the menisci was 468 mm² on the medial and 297 mm² on the lateral side. Maquet (1976) also showed the contact area under a load of 2500 N by similar

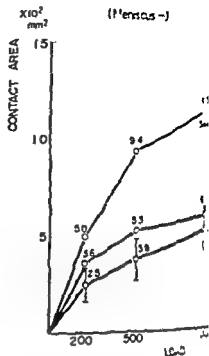


Figure 5b Contact area vs load for degenerated knees without menisci.

methods. In the fully extended position, the contact areas were 20 cm² with menisci and 12 cm² without menisci. With knee flexion, the contact areas decreased, with 60° flex on the knee, the contact areas were 12 cm² with menisci and 7 cm² without menisci. The contact areas in these reports were rather larger than our results. The reason for this discrepancy is probably due to the experimental methods and due to the different ethnic origin of the specimens. We used the casting method because it is possible to obtain a more accurate contact area compared with the roentgenographic method, though the casting material had to be removed and ligaments had to be cut. From Walker's reports (Walker & Park 1975; Walker & Erkman 1976), the contact area was 1514 mm² with menisci and 320 mm² without them at a load of 3200 N. These figures, especially those without menisci, were much larger than our results. This was presumably due to the casting method because he used bone cement, which is greater than that of a

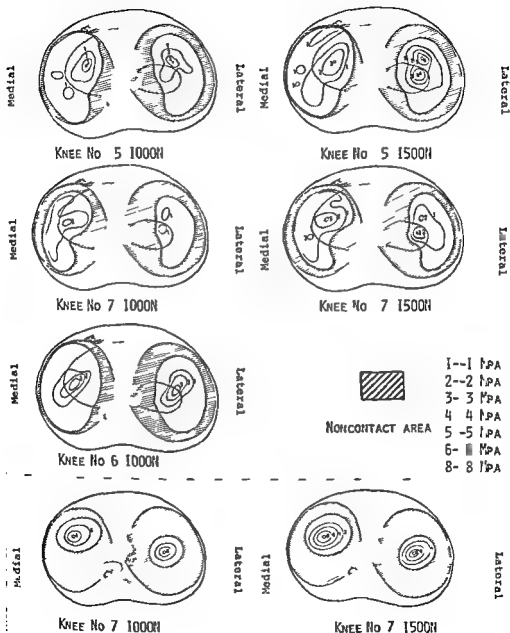


Fig. 6 Schematic views of the pressure distribution patterns at 1000N and 1500N load with and without menisci. Note menisci undergo certain pressures especially on the lateral side

Kettelkamp et al (1972) and Walker et al. (1972, 1975) reported that the medial side had a larger contact area than the lateral but Maquet (1976) described that they were about the same. In our experiment the medial contact areas were 25 per cent greater than the lateral at a load of 1000N. After removal of the menisci the difference increased to 30 per cent. However, considering that the medial tibial plateau is bigger than the lateral, the percentage contact areas on the respective condylar surfaces were almost the same at higher loads.

Walker & Erkman (1975) measured the contact pressure with miniature pressure transducers at 30° flexion. They reported that the highest pressures were on the lateral meniscus and on the medial exposed cartilage close to the medial eminence. Walker's results seemed to be consistent with ours. In our cases the highest pressure concentration was on the uncovered cartilage in the medial compartment, and in the lateral compartment on the meniscus as well as on the exposed cartilage. From these results, it is obvious that the menisci, especially the lateral meniscus, carries a significant portion of the total load applied. Thus after removal of the menisci, high pressure is imposed on the small area of exposed cartilage and degenerative processes presumably commence. So in cases of meniscal injury, the need for meniscectomy should be carefully assessed. From our results partial as opposed to total meniscectomy is to be recommended.

2. Differences in the roles of medial and lateral menisci

In anatomical terms there are some differences in the medial and lateral menisci. The lateral meniscus is a round-C shape compared with the medial one with a lazy-C shape. Moreover the lateral meniscus has a free periphery not attached to the capsule or tibia in its posterior half and therefore has more mobility than the medial meniscus which is fixed along its entire periphery by

the meniscotibial and meniscocapsular ligaments.

From the present study it was found that the lateral meniscus occupied a greater percentage area in the lateral compartment than did the medial meniscus in the medial compartment and the difference is significant ($P < 0.01$). Accordingly it may be said that the lateral meniscus contributes more to weight bearing in the lateral compartment than the medial meniscus in the medial compartment. In contrast the medial meniscus plays a more important role in joint stability. Thus does the lateral meniscus judge from its anatomy and our results.

3. Interrelation between degenerative changes and the functions of the menisci

This is a very interesting issue concerning the genesis and development of osteoarthritis of the knee. Bennett et al. (1942) and two of the earliest and most consistently affected areas in the knee were the two portions of the tibial plateau anteriorly. Miwa et al. (1972) pathological study of degenerated knees of Japanese were the most frequently at the medial and lateral uncovered cartilage areas, though the extent of the changes was not constant. From these facts, presumably one of the functions of the menisci is to protect the cartilage from excessive pressure and degeneration. On the other hand, from our experiments the medial areas were considerably larger in degenerated knees compared with the lateral ones, and the menisci, which were worn out, still played a part in broadening the area of contact. Widening of the contact area in osteoarthrotic knees is thought to be probably due to wear at the central portion of the tibial plateaus (Bennett et al. 1942). As a result the average contact area was smaller in osteoarthrotic knees than in a normal knee due to the wider contact area, but it is not certain that this would be stress attenuation in the subchondral bone of osteoarthrotic knees. In a case of severe

arthrosis (no 4) reduction of the contact area after removal of the meniscus was small (Figure 5b). From this it can probably be concluded that in arthrotic knees menisci play a less significant role in transmitting weight than they do in intact knees.

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COMPUTED TOMOGRAPHY IN SOFT TISSUE DISORDERS OF THE LOWER EXTREMITIES

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Computed Tomography (CT) constitutes an important new imaging modality in the evaluation of soft tissue tumors. They are detectable by CT because their density is different from that of muscles and because they cause displacement of normal structures. CT was found to be useful in demonstrating the true extent of lesions in the soft tissue of the lower extremities of 24 patients as confirmed by examination of the surgically removed tumors. CT was also able to define the lesions' relation to and involvement with the surrounding tissue. We were not able to distinguish between benign and malignant lesions by CT. Generally, the specific attenuation values were not helpful in differentiation between various types of tumors. However, in cases of tumors such as lipomas, cysts and neurofibromas it may be of some use.

Key words: Computed Tomography, extremities, soft tissue tumors

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In recent years the management of primary malignant soft tissue tumors of the extremities has changed from mainly amputation to either *en bloc* or muscle group resection. Proper planning of this treatment requires precise knowledge of tumor location, size, margination and involvement of surrounding structures.

The purpose of the present study was an evaluation of our preliminary experience with Computed Tomography (CT) examinations of patients with soft tissue disorders of the lower extremities.

PATIENTS AND METHODS

From November 1977 to October 1979 24 patients were referred at random for CT evaluation of soft tissue disorders of the lower extremities. The material comprises 13 males and 11 females ranging in age from 2 to 85 years with a median age of 41.

Examinations were performed with an EMI 5005 CT whole-body scanner with a scan time of 18 seconds. Slices of the suspected area, 13 mm thick, were obtained at intervals of 2 cm until the scans were similar and symmetrical to those on the normal side. For this reason great care was taken to obtain a symmetrical positioning of the lower extremities in the scanner. Characteristic bone marks on the two extremities should show the same cross-section.

Attenuation values of the soft tissue lesions were obtained in all cases. Contrast material was not used routinely, however, an attempt was made to differentiate between a lymphangioma and a hemangioma by infusing Urografin® into a 2-year-old boy.

In four cases with a suspicion of pulmonary metastases the examination of the lower limb was supplemented by a CT of the lungs.

RESULTS

Table 1 shows the final diagnoses of the 24 patients examined by Computed Tomo-

Table 1 Final diagnoses of patients with lesions of the lower extremities examined by Computed Tomography

Final diagnosis	No of patients
Normal conditions	3
Benign lesions	
Cysts	3
Neurofibroma	1
Lymphangioma	1
Myositis ossificans	2
Abscess	1
Malignant lesions	
Fibrosarcoma	4
Liposarcoma	4
Ewing's sarcoma, extrasosseous	2
Lymphosarcoma	1
Leiomyosarcoma	1
Rhabdomyosarcoma	1

graphy

CT scans demonstrated normal conditions in three patients. Also histological examinations of surgical biopsies proved normal conditions and the initial clinical suspicion of a lesion was allayed at subsequent clinical examination.

Cysts and neurofibromas (Figure 1) in CT

scans are seen as well-defined uniform appearance and a low value which for cysts equals that (0 Hounsfield Units) and for \approx 35–40 Hounsfield Units. Normal have an attenuation value of 80 Hounsfield Units.

Myositis ossificans and abscesses poorly delineated and had a varied attenuation pattern. Pronounced appeared in scans from two myositis ossificans (Figure 2) \approx the slight calcifications often malignant soft tissue tumors, \dagger and subcutis covered lesions of nature.

All patients except one with lesions were treated surgically predicted extent of the disorder confirmed. The non-operated patient had abscess and was treated with antibiotics.

Patients with malignant tumors had cases the diagnoses as stated by histological examinations and the extent the tumors displayed by CT was

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Figure 1 Distinctly outlined neurofibroma in the right thigh. A rim of fat surrounds the lesion and the muscles are displaced.

Figure 2 Myositis ossificans in the left thigh distinctly delineated with a few coarse calcifications. The bone and subcutaneous tissue are unaffected.

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Figure 3 Liposarcoma in the thigh of a 27-year man. Attenuation value was minus 80 Hounsfield Units.

only confirmed either after amputation or excision of the tumors from 10 patients. No treatment was not employed in one patient with general dissemination of a liposarcoma and in another patient with invasive tumor growth into the pelvic organs. In addition, bone affection was demonstrated in two cases.

The attenuation values in malignant tumors varied from 18 to 45 Hounsfield Units and were not correlated with the histological diagnoses. However, a liposarcoma with a high proportion of fat showed an attenuation value below zero (Figure 3) and resembled the play of lipomas with attenuation value of approximately 80 negative Hounsfield Units. Most of the tumors were located in the thigh but in two patients the tumors were found in the calf. The CT examination gave important and precise information about the extent of tumors in the proximal femur by detecting lesions in a region which is difficult to examine by other means (Figure 4

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Figure 4 (a) Indistinctly delineated liposarcoma in the left femur. Invasive growth into the muscles, fat and subcutaneous tissue. The attenuation value was positive. (b) The proximal extent of the tumor. The patient examined in the prone position.

CT examination of the lungs in two patients revealed multiple small metastases not demonstrable by conventional X ray (Figure 5 a,b).

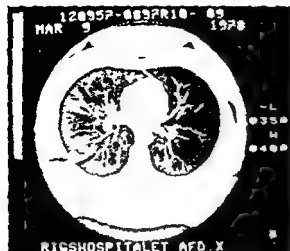


Figure 5 Lung metastases from a fibrosarcoma of the left calf in a 20-year old man. (a) Local resection of the subpleural metastasis, also seen on a conventional lung film, was planned (b) However, CT examination of the lungs revealed multiple small metastases

DISCUSSION

Computed Tomography (CT) provides an excellent means of visualizing the cross-sectional anatomy of the extremities (deSantos et al 1978, Wilson et al 1978, Hermann & Rose 1979). The soft tissue components can be compared bilaterally. The muscles are outlined clearly by the surrounding fat and in most cases the major nerves and vessels can be visualized.

Figure 6 Liposarcoma in the right n. part. invasion of the tumor into the surrounding

The present study indicates that CT is a valuable examination for localizing tumors in the soft tissue of the lower extremities. The dimensions of the tumors in all directions were correctly determined and, moreover, tumor involvement in the surrounding tissue was further than indicated by clinical examination.

CT was a particularly useful examination in obese patients and in patients with tumors localized proximally in the femur where palpable and angiographic information might be equivocal. CT was helpful in the decision as to whether *en bloc* resection or amputation should be performed.

CT was not always able to distinguish between benign and malignant lesions. Benign and non-aggressive malignant tumors might have a well-defined outline with a uniform cross-sectional appearance (Figure 6). However, malignant lesions were often distinctly delineated and the fat planes around muscles, vessels and nerves were missing in these cases. The invasive growth into the normal structures could

visualized by CT (Figure 4 a) Moreover, the malignant tumors often displayed a speckled appearance due to calcifications, hemorrhage and necrosis. Abscesses may be well-defined in outline but an indistinctly outlined abscess may give the same appearance in CT as a malignant tumor. The attenuation value of the lesion may give a hint as to the diagnosis in the case of abscesses, cysts and neurofibromas but an overlapping of the values of different lesions obscures this possibility (Hunter et al. 1979, Santos et al. 1978). Moreover, tumors of the same histologic type may display different attenuation values. In the present study three sarcomas had positive values and a fourth negative one. All lesions, benign as well as malignant, had attenuation values lower than that of muscle so that no problems were encountered in defining the lesions. But tumors isodense with the surrounding muscles have been described (Levine et al. 1979). In this case infusion of contrast material may be helpful. Intravenous infusion of contrast material also facilitates demon-

stration of the vessels (Levine et al. 1979, Heelan et al. 1979).

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COMPUTED TOMOGRAPHY OF MUSCULOSKELETAL DISORDERS OF THE TRUNCUS

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Computed Tomography (CT) is a new diagnostic tool in the evaluation of three-dimensional extent of lesions, but in about one-third of the cases the examinations were not able to distinguish between benign and malignant lesions.

Key words: Computed Tomography, bones, Computed Tomography, muscles, bone neoplasms, bone infections

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The remarkable advantages of Computed Tomography (CT) are the graphic and numerical recordings of very small differences in radiation attenuation as well as the presentation of a transverse body section (Hounsfield 1973, Schumacher *et al* 1978). The specific X-ray attenuation values obtainable by CT make it, in comparison with conventional roentgenology, a far more specific and precise method of establishing the presence of calcium, fluid or fat (Hunter *et al* 1979).

Preoperative evaluation by this technique helps to establish the feasibility of surgical resection and the proper surgical approach especially for lesions in and around the axial skeleton and pelvis. If surgery cannot be performed CT is useful in the planning of radiation therapy. The purpose of the present study is to evaluate the value of CT scanning in disorders of the musculoskeletal tissues in the body.

PATIENTS AND METHODS

The examinations were performed with an EMI 5005 CT whole-body scanner with a scan time of 18 seconds. Slices of the suspected area, 13 mm thick, were obtained at intervals of 2 cm.

Forty-four examinations were performed in 29 patients with known or suspected tumours of the axial skeleton and pelvis during a 2-year period. The patients included 11 males and 18 females ranging in age from 1 to 76 years with a median age of 31. Attenuation values of the soft tissue lesions were measured in all cases. In two cases with a primary malignant tumour of the pelvis, the lungs were also scanned in order to look for metastases. Intravenous contrast material was used in three patients only. In 25 cases the diagnosis was verified either by operation or biopsy.

RESULTS

Table 1 shows the final diagnosis in 29 patients with musculoskeletal disorders of

Table 1 Final diagnosis in patients with musculoskeletal lesions of the body examined by CT

Diagnosis	No of patients
Infectious disorders	8
Benign tumours	
Neurofibroma	2
Osteoid osteoma	1
Chondroma	1
Malignant tumours	
Sarcomas	5
Swannoma	2
Clear cell carcinoma	1
Myelomatosis	1
Metastases	8
Total	29

the truncus examined with Computed Tomography

Infections

Three patients suffered from tuberculous spondylitis (Figure 1) CT of the affected bone displayed a characteristic lytic defect of the bone surrounded by a sclerotic zone. The lesions extended into the soft tissue as large, well-delineated processes with scattered



Figure 1 Tuberculous abscess in the lumbar spine with bone destruction and a well defined soft tissue component containing calcifications

Figure 2 A well defined lumbar paraspinal with bone affection. Non specific infection.

calcifications. Two of these patients gravitation abscesses.

In three cases with non-specific osseous infections, central defects surrounded by sclerotic zones were also seen but calcifications were found in the soft component of these infections (F). Two patients with abscesses had of bone. Examination of biopsy confirmed the infectious disorders.

Sequential examinations by CT performed in two patients to estimate effect of antibiotic treatment. In one with spondylitis the soft tissue involvement was seen to diminish in the course of the examinations. In a case of tuberculous abscess the lack of effect could be seen in correlation to the clinical view.

Benign tumours

Neurofibromas showed a uniform cross sectional appearance with a well-defined outline. The attenuation values were 31 Hounsfield Units. CT displayed erosion of the pedicle in one patient with the neurofibroma near the spine (Figure 3a and b).

An osteoid osteoma was found near the sacroiliac joint in a 12 year-old girl with persistent pain. Slight sclerotic alterations

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3 a) A parasagittal mass near the right kidney. It can not be distinguished from kidney. b) After i.v. contrast enhancement of kidney the mass - a neurofibroma - can be distinguished.

by conventional X ray but CT revealed a characteristic well-delineated sclerotic lesion with a small rarefied central nidus (Figure 4). A chondroma was located in a thoracic vertebra. The lesion was difficult to classify. Examination of the surgically removed vertebra led to the diagnosis.

Significant tumours

The material includes 17 patients with significant diseases. Eight of these patients were referred because conventional X ray had

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Figure 4 An osteoid osteoma of the sacrum showing sclerosing with central rarefaction

shown solitary osteolytic tumours in the skeleton. Histological examinations of biopsy material disclosed that these lesions were metastases from distant primary tumours located in the prostate gland, kidneys or the GI tract. The CT examination showed expansive destruction of the bone with involvement of surrounding soft tissue where discrete calcifications were seen. These lesions were poorly delineated (Figure 5) and in two patients invasive growth into the subcutis and the cutis was seen.

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Figure 5 Large soft tissue/osseous metastases to the sacrum not visible on conventional films

The lesions due to myelomatosis displayed an appearance very similar to that of metastases

The primary malignant tumours were seen in four of the five patients with sarcomas as indistinct bone destructions with lytic and sclerotic areas and large but poorly defined soft tissue involvement

In the other five patients the malignant tumours were visualized as well-delineated homogeneous lesions in the soft tissue. In this group of patients the CT examination in two cases was supplemented by CT of the lungs revealing multiple small metastases in one case

Surgical extirpation of the tumours was only indicated in three cases with benign tumours and in five cases with malignant tumours. The extent of the tumours predicted by CT was confirmed in all these cases.

In about half the cases CT contributed definitely to the diagnosis, either by revealing lesions not suspected clinically (four cases) or by showing unsuspected extension of tumours and infections. In 25 per cent of the cases CT findings changed the therapy. CT was not misleading in any case.

DISCUSSION

The material comprises patients with a variety of disorders in the axial musculoskeletal system. Most patients were referred for CT scanning in the hope of obtaining more information about suspected lesions or the extent of known lesions. A few patients were referred for CT examination in order to gain experience with the CT-scanner in this field of pathology.

Because of considerable overlapping it was not possible to differentiate the various lesions on the basis of attenuation values.

CT was not able to differentiate between benign and malignant tumours in all cases in accordance with the findings of deSantos et al (1978). Some malignant tumours were well-defined and showed a homogeneous



Figure 6 A malignant Sarcoma in the psoas muscle. A well defined tumour & osseous affection.

cross-sectional appearance very similar to that of benign tumours (Figure 6). Moreover, the expansive growth of a benign tumour in the soft tissue could erode the adjacent bone, resembling invasive tumour growth. Infections of the musculoskeletal system did not show any definite characteristics, but could mimic a tumour.

However, certain characteristics were found to give a hint of the correct diagnosis. In the cases of osseous involvement, benign tumours and infections showed a lytic lesion surrounded by a sclerotic zone, while malignant tumours displayed poorly delineated bone destructions, often more extensive than expected from the conventional X-ray. The same poor delineation of the soft tissue component was seen in aggressive malignant tumours, while well-delineated processes could be seen in benign tumours as well as malignant.

Where surgery was performed in accordance with the findings of Wilson et al (1978), the CT examination predicted the extent of the lesions was confirmed. This was in accordance with the findings of Wilson et al (1978).

In the pelvic and in the paraspinal soft tissue lesions were demonstrable by CT (Figure 7) while conventional methods did not

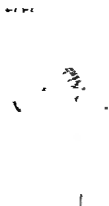


Figure 7 Liposarcoma of the pelvis with destruction of the left iliac bone. The extensive intra- and pelvic soft tissue component was larger than initially suspected

and gave insufficient information as also noted by Levine et al. (1979). The precise information concerning the size of the tumours in the surrounding tissue is of great value for the further management of the patient. Gulla et al. (1979) found that CT complemented the clinical and routine radiographic diagnosis in 25 out of 26

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Figure 8 Ewing's sarcoma of the right iliac bone in a patient with only one kidney. In planning the radiation field it was important to visualize the position of the kidney

tumours of the osseous pelvis studied by CT. Surgery and radiation therapy planning can be optimized (Figure 8). Moreover, with CT reproduction of the cross-sectional cuts is easy and tomography can thus serve as a parameter for medical or radiation therapy by comparing sequential examinations.

CT examinations are non-invasive in most cases. Intravenous contrast injections have been used in a few patients to improve the visualization of major vessels or the urinary organs related to a tumour. In tumours isodense with the surrounding tissue, IV injection of contrast facilitated the detection of a tumour (Figure 3b). In cases of soft tissue tumours and infectious disorders IV control should be used more consequently.

In conclusion, CT is an easy and effective method of displaying the full three-dimensional extent of musculoskeletal disorders of the body. Only in a few cases was the CT examination *per se* able to establish the diagnosis.

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THE EFFECT OF JOINT POSITION ON JUXTA-ARTICULAR BONE MARROW PRESSURE

*Relation to Intra-articular Pressure and Joint Effusion -
Experimental Study on Horses*

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Six metacarpo-phalangeal joints of adult horses were studied. Pressure measurements were made in the joint and the metacarpal bone with simultaneous measurement of the systemic arterial blood pressure. Investigations performed to study the effect of joint position on juxta-articular bone marrow pressure showed that an increase in joint flexion was always followed by a rise in intraosseous pressure with a significant increase at flexion above 60 degrees. Increase in intra articular pressure which was achieved by injection of saline was always followed by a slower rise in intraosseous pressure. Furthermore, it was shown that even a few millilitres of saline in the joint caused a rise in intra articular pressure.

The findings indicate that changes in joint position as well as effusion may block the drainage vessels from the bone marrow as they pass through the joint.

Keywords: intra-articular pressure, intraosseous pressure, joint effusion

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Joint effusion as seen in various types of arthritis is accompanied by a rise in intra-articular pressure (Eyring & Murray 1964). It has been shown in patients with rheumatoid arthritis of the knee joint that the intra-articular pressure in the presence of joint effusion is least in the mildly flexed position and that further flexion produces extremely high intra-articular pressure (Favreau & Eyring 1963, Eyring & Murray 1964, Jayson & Dixon 1970).

Recently, it has been shown (Arnoldi et al 1979) that increasing intra-articular pressure—induced by injection of saline into the knee joints of rabbits—was followed by a rise in the juxta-articular bone marrow pressure of the femoral condyle. These findings indicate that changes in the joint position may influence intraosseous pressure, however, no attempt has so far been made to assess the correlation between joint position and intraosseous pressure.

This study describes an experimental investigation to find whether such a relationship exists and to explore the correlation between the volume of joint effusion and the intra-articular pressure.

This study was supported by a grant from the Danish Medical Research Council project number 7-10625

MATERIAL AND METHODS

Six adult horses weighing 255–515 kg were used for the experiments which were performed under Halothane anaesthesia. Blood pressure, intra-articular pressure of the metacarpo-phalangeal joint of the forelegs (fetlock joint) and intraosseous pressure of the juxta articular bone marrow of the metacarpal bone were measured simultaneously

Experimental procedures

Blood pressure was measured continuously through a venflon cannula in an artery of the hindleg

The intra articular pressure of the metacarpo-phalangeal joint was measured through a 1.2 mm cannula. An image intensifier and infusion of isotonic Ampaque (Nyegaard & Co., Oslo Norway) were used to check that the cannula was situated in the joint cavity. In three of the experiments a second cannula was placed in the joint and connected to a perfusor pump to record the volume of saline injected simultaneously with the measurement of the pressures. The rate of infusion was 10 ml/min

The intraosseous pressure was recorded through a 1.8 mm marrow aspiration cannula which was drilled into the distal part of the metacarpal bone until the tip of the cannula reached the juxtachondral bone. The image intensifier was used to control the position (Figure 1). Before connection to the measuring system the cannula was flushed with heparin saline.

The cannulas were connected to the pressure recording system (Hansen HB 66 manometers Simonsen & Weel, Albertslund, Denmark) by means of manometer lines (Portex, Hythe, England) and three-way stop-cocks. For pressure recording an Ultralette 5671 (Atlas Copco, Bromma Sweden) was used.

Radiographs of the joints investigated were all normal and no clinical symptoms had been observed. In the standing position the metacarpo-phalangeal joints in the horse are loaded in slight hyperextension. The attachment of the joint capsule and the extension of the joint cavity with its recesses were demonstrated by arthrography (Figure 2).

The following investigations were carried out

- (1) At different degrees of flexion (from hyper extension to maximal flexion, i.e. about 110 degrees above right angled position) corresponding intraosseous pressures were recorded
- (2) At different values of intra articular pressure – obtained by infusion of saline – corresponding intraosseous pressures were recorded simultaneously

- (3) In three of the six joints volume of injected saline the pressure and the intraosseous recorded simultaneously in relation of infusion.

RESULTS

Correlation between joint position and intraosseous pressure

Figure 3 shows intraosseous pressure at different degrees of flexion in the investigated joint. The figure shows a significant ($P < 0.05$) and above this from 60 to 80 degrees – the rise in intraosseous pressure was highly significant ($P < 0.01$). Intraosseous pressure exceeded systemic blood pressure but this



Figure 1 Radiograph of the left metacarpo-phalangeal joint of a horse (fetlock joint) showing the cannulas one in the juxtachondral bone marrow of the metacarpal bone and one in the joint cavity



Figure 2 Arthrography of the metacarpophalangeal joint illustrating the dimensions of the joint cavity with recesses communicating with the joint

Correlation between intra articular and intraosseous pressure

Figure 4 shows that increasing intra articular pressure — with infusion of saline — was always followed by increasing intraosseous pressure. The values were positively correlated with a coefficient of correlation at 5077 (Spearman coefficient) and $0.5 > P > 0.02$.

Correlation to the volume of injected saline

Figure 5 shows simultaneous pressure curves from a single experiment. An almost immediate rise in intra articular pressure was

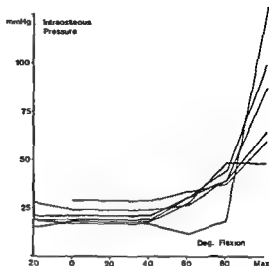


Figure 3 Diagram showing the relationship between degree of flexion and intraosseous pressure in the six joints investigated

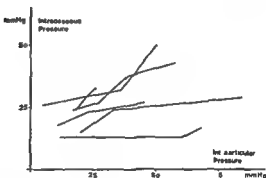


Figure 4 Diagram showing the relationship between intraosseous and intra-articular pressures

recorded with infusion of saline followed by a much slower rise in intraosseous pressure — after 1 minute — corresponding to 10 ml saline

DISCUSSION

In patients with painful osteoarthritis increased intraosseous pressure accompanied by phlebographic signs of impaired venous drainage is a well known feature

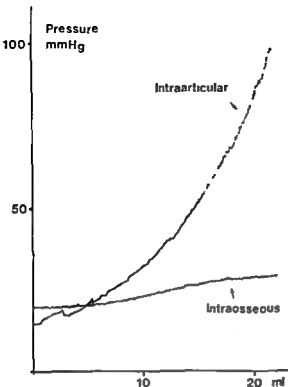


Figure 5 Curves from a single experiment with simultaneously recorded intra articular pressure, intraosseous pressure and volume of injected saline in ml. The rate of infusion was 10 ml/min

(Arnoldi et al 1972) The suggestion that this intraosseous hypertension in the juxta-chondral bone marrow may be secondary to high pressure in the joint cavity due to synovitic effusion has been supported recently by an experimental study of interdependence between intra-articular and intraosseous pressure in knee joints of rabbits (Arnoldi et al 1979). In the present experiments a similar correlation between intra-articular and intraosseous pressure was found. Increased intra-articular pressure — induced by injection of saline into the joint cavity of metacarpophalangeal joints in horses — was followed by increased intraosseous pressure in the juxta-chondral bone marrow of the metacarpal bone.

As shown by Eyring & Murray (1964) the intra-articular pressure increases when the

volume of synovia increases or when the space is reduced. They have shown a correlation between the hydrostatic pressure of effusion and the joint's position. Therefore seems likely that changes in the position of the joint could cause changes in intraosseous pressure.

In accordance with the principles of Helsinki declaration this pilot experimental study was carried out on metacarpophalangeal joints of horses — frequently seat of osteoarthritis. This joint is a joint very similar to human joints and recesses communicating with the joint or as confirmed by arthrography. It is therefore considered suitable for the investigations in the present study.

We are well aware that in diseased joints changes other than effusion in the joint contribute to changes in the intra-articular pressure, for example, contractures in joint capsule and swelling of the synovial membrane.

Our findings have shown that intraosseous pressure in the juxta-articular bone marrow was influenced by the position of the joint. Thus flexion above 60 degrees caused a significant rise in intraosseous pressure. A rise in intraosseous pressure induced flexion is probably due to compression of draining veins from the bone marrow and pass through the joint.

In human osteoarthritis intraosseous pressure above 40–50 mmHg causes pain (Arnoldi et al 1972, Lynch 1974). The findings obtained suggest that changes in joint position may contribute to pain due to elevated intra-articular as well as intraosseous pressure.

The simultaneously recorded curves showed that 1–2 ml of saline in the joint cavity is sufficient to cause a rise in the intra-articular pressure followed by an increase in intraosseous pressure. These findings suggest that the intraosseous hypertension observed in patients with painful osteoarthritis could be caused by comparatively slight synovitic effusion.

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STOLOGIC, PHYSICAL AND CHEMICAL VESTIGATION OF MYOSITIS OSSIFICANS TRAUMATICA

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Histologic, physical and chemical analyses of the excised bony mass from a case of myositis ossificans traumatica were carried out. X-ray diffraction showed that the newly formed bone was an intermediate fluor-

batic environment.

Key words: myositis ossificans traumatica, apatite, X-ray diffraction, infrared spectroscopy

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Myositis ossificans traumatica was first described in the 18th century by Frencké & Popping (Morger 1964). Various locations have been reported (Coley 1913), Schneider & Jakob 1966, Jackson & Feagin 1973) and the histology of this condition has been outlined by Geschickter & Maseritz (1938).

No physical and chemical analysis of this type of ossification however was found in the available literature. In the following a patient with myositis ossificans traumatica will be described, operation on this patient gave an opportunity to carry out a complex investigation of the newly formed calcified mass.

PATIENT AND METHODS

A male 39 years old sustained a blunt injury on the inner side of his left thigh. Two months later a calcified mass developed in the adductor musculature causing mild pain and restriction of movement. The calcified mass was excised and investigated histologically* and using complex radiographic methods.

The authors are indebted to Dr K. Aszódi for the histologic examination.

The microscopic examination revealed an enlargement of numerous muscle fibres and the narrowing of others. Between these fibres abundant, actively proliferating connective tissue, more deeply lobulated or insular cartilaginous areas with several mitotic chondrocytes could be observed. In many places the formation of osteoid trabeculae and irregular cancellous bone could also be seen with oedematous hyperaemic connective tissue in the medullary cavities (Figure 1, A and B). Histologic diagnosis: myositis ossificans.

The remainder of the excised mass was prepared and investigated by X-ray diffraction, infrared spectroscopy and chemical analysis as described earlier (Pintér et al. 1979).

RESULTS

X-ray diffraction (Figure 2) This revealed that the excised bony mass contained a low grade crystalline apatite, similar to that of physiological bone hydroxylapatite. The crystallites of this mineral were however finer than that of normal bone. The average crystallite size of other pathologic calcifications e.g. calcinosis, osteochondromatosis (Pintér et al. 1975, Pintér et al.

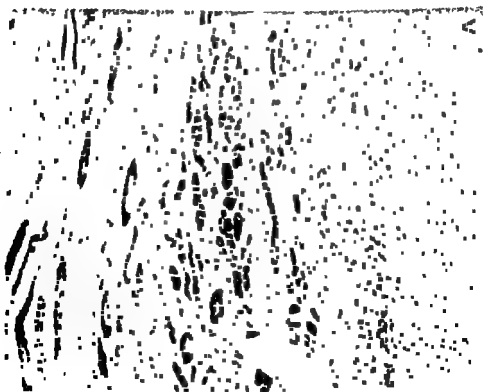
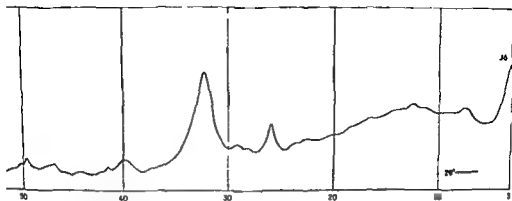


Figure 1. A. B. Histomicrographs demonstrating the typical normal pattern of muscle tissue.



2 X ray diffractogram of the excised bony mass from myositis ossificans traumatica. The pattern an intermediate fluor hydroxylapatite variant

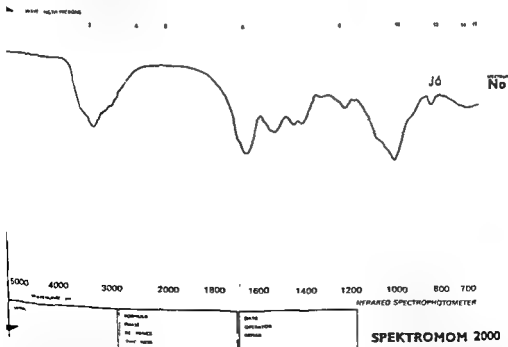
on the contrary greater than that physiological bone hydroxylapatite. It be assumed that the sample in ated was an intermediate fluor-oxylapatite

fluor and hydroxylapatite were however visible. The specimen contained most probably a fluor hydroxylapatite variant

Chemical analysis The compounds found in the wet chemical analysis are presented in Table 1

Ca, P and F seemed to be the major constituents, several minor constituents were

ed spectroscopy (Figure 3). No signs of ate could be found incorporated in the 1 lattice. The characteristic bands of



3 Infrared spectrum of the excised bony mass from myositis ossificans traumatica. The characteristic bands of fluor and hydroxylapatite can be observed together with signs of organic and free contamination

Table 1 Wet chemical analysis of the bony mass excised from myositis ossificans traumatica. The minor elements belong to isomorphous substitution in the crystal lattice of the apatite

	Per cent
SiO_2	0.3
TiO_2	0.00
Al_2O_3	0.00
Fe_2O_3	0.05
CaO	28.10
MgO	0.46
SrO	0.00
Na_2O	0.31
K_2O	0.05
P_2O_5	21.80
CO_2	0.10
F	1.28
Cl	0.07
Ignition loss	47.69
H_2O from this	5.0
Organic C	18.5
O loss	0.55
Sum total	99.66

also found. The P/Ca ratio proved to be 1.55. It is probable that the sample consists of a rather pure hydroxylapatite variant. The crystallochemical formula of the apatite investigated, based on exact crystallochemical calculations, was as follows:



DISCUSSION

There was an important difference between the mineral parts of the ossified specimen from myositis ossificans traumatica and other pathologic calcifications investigated previously. The mineral part of articular osteochondromatosis free bodies and calcinosis resembled apatites built up in a fossilitic

environment, i.e. in an acidic and CO₂ environment (Brophy & Nash-McConnell 1938).

The apatite investigated here resembles the other hand the accessory apatites in the basal rocks. The differences between the specimen investigated and these apatites were as follows: the crystallite size was less and the inner structure less developed in the part of the mass from myositis ossificans traumatica than in the rocks mentioned. It can be assumed however that similar to the basal rocks the formation of the mass investigated occurred in alkaline solution in an environment abundant in O₂ and poor in CO₂.

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HAEMANGIOPERICYTOMA OF BONE

Review of the Literature and Report of a Case

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A case of intraosseous haemangiopericytoma of the humerus is described. Exarticulation at the shoulder joint was performed and the patient has been followed for 8 years, so far without developing a local recurrence or metastases. The 16 cases of intraosseous haemangiopericytomas on record are reviewed.

Key words: haemangiopericytoma, malignant bone tumour, sarcoma

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Haemangiopericytoma is a relatively well-known type of tumour, but its intraosseous variant is extremely rare. The intraosseous variant was first described by Stout in 1956, and to our knowledge only 16 cases have been published in the medical literature (Table 1). Intraosseous haemangiopericytoma is a malignant tumour characterized histologically by proliferation of fairly uniform, round, oval spindle-shaped pericytes arranged around irregular vascular lumina lined with a single layer of endothelial cells. The frequency of metastases may vary widely from tumour to tumour. A radiological manifestation is usually a lytic process which in some cases may expand and perforate the cortical bone, or completely destroy the involved bony area.

CASE REPORT

The patient was a 69-year-old man, formerly a farmer who had always been in good health. In the spring of 1969 he developed pain in the region of the right shoulder. The pain subsided in a few weeks, but returned a couple of months later.

Then the patient consulted a doctor. The condition was interpreted as humeroscapular periarthritis and was treated with analgetics. No X-rays were done at that time. During the subsequent year the patient had only negligible complaints on account of the arm, but in July 1970 a minor trauma elicited more intense pain in the right shoulder. This time the patient did not visit his doctor, but in the course of the autumn and winter he noted swelling of the upper arm. In March 1971 he re-visited his doctor who referred him for an X-ray examination which revealed a large tumour of the right humerus (Figure 1). The patient was admitted to the local hospital where a biopsy was taken. It showed haemangiopericytoma, and the patient was immediately transferred to a tumour centre. On admission there he was found to have a firm, indolent tumour proximally in the right upper arm. X-rays of the skeleton showed no tumours elsewhere, and chest radiography showed normal appearances. The ESR was 11 mm/h, alkaline phosphatases 166 (normal range 3-10). Exarticulation at the shoulder joint was performed on 14/7/71. The postoperative course was uneventful. The patient was supplied with a prosthesis, but he has never learnt to use it. Throughout he has been regularly followed in the outpatient department of the tumour centre, where he was last seen in April 1979. There have been no signs of local recurrence and no signs of metastases. The latest chest radiography, from April 1979, was normal.

Table 1 Number of cases, their ages and the localization of primary haemangiopericytoma: the materials published so far

Author	No of cases	Age (years)	Site of tumour
Stout (1956)	2	29-32	Femur-Fibula
Marcial Rojas (1960)	1	III	Clavicle
Legré et al (1966)	1	58	Femur
Unni et al (1971)	4	33-64	Rib Thoracic vert Pelvis (2 cases)
Gerner et al (1974)	1	62	Lumbar verteb
Huvos (1979)	6	15-48	Femur (2 cases) Humerus (2 cases) Scapula Pelvis
Wolkow (1979)	1	13	Femur
Present authors	1	69	Humerus
Total	17		Extremities 9 cases Trunk 8 cases

HISTOPATHOLOGY

After the humerus had been sawn in the frontal plane a greyish white, lobulated intraosseous tumour, 8 × 6 × 6 cm, was revealed (Figure 2). In places it had destroyed the cortical bone (Figure 1) and infiltrated the surrounding soft tissues. Microscopic examination showed an extremely cellular tumour consisting of many thin-walled, ramifying vessels of varying calibre surrounded by randomly oriented, densely packed cells with round or oval nuclei without major polymorphism (Figure 3). The cytoplasm was on the whole translucent with indistinct cell borders. Reticulin staining disclosed that throughout, the tumour cells were separated from the endothelial cells of the vessels by a distinct basement membrane (Figure 4). In some places there was penetration of the bone with destruction of the cortical bone and infiltration of the surrounding muscles. There were 5-10 mitoses per 10 high-power fields, no necroses, and no haemorrhage except at the biopsy site. Phosphotungstic acid-haematoxylin (PTAH) staining did not disclose any myofibrils, there was no differentiation into a chondroid matrix and no storiform pattern.

Histological diagnosis Characteristic haemangiopericytoma. According to the criteria of Enziger & Smith (1976) and McMaster et al (1975) it must be classified as malignant.

DISCUSSION

Like other malignant tumours of intraosseous haemangiopericytoma itself primarily by regional pain. pain may be intermittent, and in some the tumour grows slowly, so that years may elapse before the symptoms marked enough for a diagnosis to be made.

The cases on record so far are fairly distributed as to sex and age. The tumour has been by irradiation, surgical excision or amputation. Of Stout's (1959) two cases in the femur, was treated exclusively by irradiation and the other, in the fibula, by resection. These patients are reported to have had no metastases or recurrence. The follow-up period is not mentioned. The patient reported by Marcial-Rojas (1960) with a tumour in the clavicle was treated by excision, but died with pulmonary metastases 6 years after the operation. The femoral tumour published by Legré et al (1966) was treated by excision, but the patient died with pulmonary metastases 6 years later. Out of the four



Figure 1 Radiography of the right humerus showing a large lytic process and expansion of the bone which is penetrated in places



Figure 2 Frontal section through the upper arm showing greyish-white, lobulated intraosseous tumour tissue, in places destroying the cortical bone and infiltrating the surrounding soft tissues. The central haemorrhage is presumably due to the preoperative biopsy

published by Unni et al (1971) one, affecting the femur, was treated by resection, but the patient died with metastases 16 months later. In a second case, in the body of the 2nd thoracic vertebra, was treated by excision followed by irradiation, the patient died with metastases 31 years later. The remaining two cases, in the iliac bone and ischial bone, were treated by resection followed by irradiation and hemipelvectomy, respectively. These two patients have been followed for 20 months and 9½ years without signs of metastases or local recurrence. The vertebral tumour reported by Gerner et al (1974) was treated with X-rays, and it is stated that the patient has been followed for only a short period. The six

cases published by Huvos (1979) were treated by wide surgical excision or amputation, followed by chemotherapy. Three of these patients have died with metastases. One — treated solely with X-rays — was alive with a local recurrence 11 years after the treatment. One patient with a scapular tumour was alive 15 years after X-ray treatment and subtotal excision of the tumour and, 9 years later, excision of a solitary pulmonary metastasis. In the sixth case the follow-up is still too brief. Wolkow (1979) has published one case, but does not report the treatment or the course.

Summing up, then, of the six cases reported so far with sufficient information and a 5-year follow-up, only four have been



Figure 3. Characteristic haemangiopericytoma consisting of thin-walled, ramifying vessels surrounded by fairly uniform, densely packed tumour cells (haematoxylin-eosin $\times 100$)



Figure 4. Reticulin staining of characteristic haemangiopericytoma pattern, tumour cells being situated outside the membrane of the vessels ($\times 23$)

tumour-free 5-year survivors. One developed metastases 6 years after removal of the primary tumour, another patient developed metastases after more than 23 years and died 31 years after primary treatment.

It must be concluded, therefore, that although an intraosseous haemangiopericytoma may be slow-growing in some

cases, it is an extremely malignant tumour. Although our patient is alive without metastases and local recurrence 8 years after operation, it should be mentioned that the tumour cannot be adequately treated by surgical removal and/or radiotherapy. It is not yet known whether chemotherapy will alter this dismal outlook.

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RACTURE OF THE CARPAL SCAPHOID CHILDREN

Clinical and Roentgenological Study of 108 Cases

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A series of 108 carpal scaphoid fractures in children was analysed with respect to the site, type and treatment of the fracture. The patients were followed until radiological fusion occurred. All fractures united and healed completely with conservative treatment. Ninety-four fractures, 41 of which were avulsions, were located in the distal third of the scaphoid. There were 13 waist fractures, and one avulsion fracture was located in the proximal pole of the scaphoid. The great number of avulsion fractures and the location of the fractures in the distal third of the scaphoid is very typical in children. In three neglected cases marked bone resorption was seen on the fracture surface 3 weeks after the injury. Because non-union is possible especially in neglected cases of waist fractures, control radiographs should be taken 1 or 2 weeks after the injury if the fracture is not visible on the primary radiographs but is suspected clinically. Immobilization with an adequate plaster cast is mandatory in all transverse fractures of the carpal scaphoid in children.

Key words: carpal scaphoid, children, fracture

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Fractures of the carpal scaphoid have been considered rare in children (Blount 1955, Lindy 1969). According to Müssbichler (1961) avulsion fractures occur more frequently and are probably more common than transverse fractures across the bone. It is generally known that fracture of the scaphoid waist in adults may occasionally lead to delayed union or even to non union. According to Watson-Jones (1976) over 90 per cent of carpal scaphoid fractures in adults will unite when treated conservatively with a plaster cast for 12 weeks. Non union of carpal scaphoid fractures is very rare in children (Müssbichler 1961, Southcott & Rosman 1977). According to Sharrard (1971) non-union seldom occurs and should be treated by bone-grafting in an adult child.

Because very few studies of carpal scaphoid fractures in children have been published we report our observations in 108 cases. Special attention was paid to the type and site of the fracture, the treatment and the results.

PATIENTS

A total of 147 children under 15 years of age with an established or suspected carpal scaphoid fracture were treated at the Aurora Children's Hospital, Helsinki, during the years 1962 to 1976. Thirty-nine patients were excluded from the study mainly because the presence of a fracture could not be established in the primary radiographs and there were no signs of a fracture in the control radiographs taken 1-2 weeks after the injury. Thus our series consisted of 108 children. At the time of the trauma they were 10-14 years of age

except for three children, two of whom were 9, and one 6 years of age. The mean age was 12.5 years and the series consisted of 75 boys and 33 girls. The left hand was fractured in 64 cases and the right in 44.

Seventy-two patients had fallen on the outstretched arm, a bicycle accident had caused the fracture in 21 patients, 8 patients had fallen from a height and in the 7 remaining cases the fracture had been caused by twisting or a direct blow to the hand in a game or in a traffic accident.

THE SITE AND TYPE OF THE FRACTURE

The generally accepted site distribution into the distal, middle (waist) and proximal third of the scaphoid bone was used. In the distal third there were 94 fractures (87 per cent), in the middle third 13 fractures (12 per cent) and in the proximal third one fracture (1 per cent) (Figure 1).

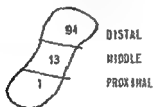


Figure 1 The sites of 108 carpal scaphoid fractures

An avulsion fracture was present in the distal third in 41 cases, 40 of these fractures were located on the dorsoradial aspect and one on the ulnar side of the distal pole of the scaphoid (Figure 2A). One avulsion fracture of the proximal pole of the scaphoid was observed. The avulsion type of fracture was always detected in the primary radiographs on the day of injury.

The most frequent type of fracture was the transverse fracture located in the distal third of

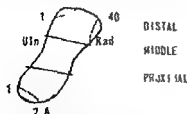


Figure 2A The location of avulsion fractures



Figure 2B The location of fissure and transverse fractures

the bone, 53 cases (Figure 2B). There was no displacement. In four of these 53 cases a small or oblique fissure was observed which extended through the whole thickness of the bone. In five (5/53) cases the fracture line through the bone could not be seen in the radiographs, there were only signs of a break in the contour of the bone. However after 2 weeks the fracture line through the bone was visible.

Fractures of the middle third were 13 cases (Figures 1 and 2B). Displacement of the fracture did not occur. The youngest patient (10 years old) had this type of fracture. In the primary radiographs but a break in the contour as in a greenstick type of fracture was visible. After 2 weeks the fracture line was seen because of osteosclerosis. In one case there was large bone resorption having a cystic appearance. In two of these three cases the injury was noticed first at the first visit to the hospital. One of these patients was 6, and the other two 14 years of age.

ASSOCIATED INJURY

A fracture of the distal metaphysis of the radius was seen in two patients, distal epiphyseal fracture of the radius in one, a typical fracture of the base of the metacarpal bone in one patient. There were also fractures (5/108, 4.6 per cent) of the first metacarpal bone. In one patient there was a fracture of the first metacarpal base on the contralateral hand.

TREATMENT

The immobilization time of a fracture of the distal third of the scaphoid varied from 10 to 9 weeks. The most common immobilization period was 4 to 8 weeks (39/94 cases). A dorsal plaster splint was used in 30 cases and a plaster cast from below the elbow to the phalangeal joint of the thumb (as recommended by Blount 1955) in the remaining 64 cases. Fractures of the middle third were immobilized in a plaster cast for 4-16 weeks in 12 cases and in a plaster immobilization for 2 weeks in one case. One avulsion fracture of the proximal pole of the scaphoid was immobilized with a cast for 3 weeks.

Of the three cases with neglected fractures, one of the two 14-year-old patients was immobilized for 12 and the other for 16 weeks.



Figure 3A A girl aged 14 years had fallen on her hand 3 months earlier. The patient had received no initial treatment. Radiograph shows a fracture of the waist of the scaphoid bone with increased bone resorption.



Figure 3C The wrist after 16 weeks' immobilization. The plaster cast has been removed and the fracture is united.



Figure 3B The appearance 8 weeks later. Increased resorption and also osteosclerosis can be seen.



Figure 3D Radiograph of the wrist 12 years later at the follow-up. Slight osteosclerosis can still be seen in the middle of the scaphoid bone.

The mean duration of the plaster cast immobilization was 6.4 weeks and the mean immobilization time when using a plaster splint was 3.3 weeks.

RESULTS

The patients were followed until the fracture was roentgenologically completely fused. The radiographs and the clinical data of all the patients were reviewed. If the patient still had some symptoms at the last clinical examination or the fusion of the fracture in the last radiograph was suspected to be incomplete the patient was asked to come for a personal follow-up. There were 21 such cases.

At the follow-up a clinical and roentgenological examination was carried out. All fractures in this series were found to be fused, including the fractures of the three neglected cases (Figure 3). All patients were free from symptoms. The range of movement of the carpal and elbow joints was normal. Because there was no non-union the result of the treatment was evaluated as good in all 108 patients.

DISCUSSION AND CONCLUSIONS

In 1978 at the Aurora Children's Hospital, Helsinki, 17 scaphoid fractures were diagnosed, which is 1.7 per cent of all fractures of the upper extremity (17/1011) in children. Fractures of the carpal scaphoid are rare compared with other fractures of the upper extremity. The patients with a diagnosed scaphoid fracture were predominantly over 10 years of age and the mean age was 12.5 years. This is logical because the ossifying centre appears on the radiograph at approximately 5–6 years of age, the range being 2.5–9 years (Tachdjian 1972).

The site of the fracture was clearly different from the distribution of corresponding fractures in adult series, where fractures of the middle third have been reported to be most frequent (Andersen &

Therkelsen 1949, Mazet & Hohl 1963, Kankaanpää 1975). In Alho's (1973) a more than 1 mm displacement of fracture was present in 23 per cent of cases. We did not observe such a displacement.

Avulsion or incomplete fissure type fractures were present in 42.5 per cent of cases and were most frequently located in the distal third of the scaphoid. This is in agreement with Müssbichler (1961), who reported avulsions in 52 per cent.

The difficulty diagnosing avulsion fissure types of fractures and the importance of radiographs of the oblique and proximal projections were emphasized by Lehto (1949) and Müssbichler (1961), with whom we also agree. Clinically these types of fractures have no great significance because they all heal rapidly. Naturally some of the avulsion or fissure types of fractures, which are not visible on the primary X-ray picture, can be diagnosed in the radiographs taken 2 or 3 weeks after the injury.

The scaphoid bone is vascularized by intra- and extraosseous pathways and the proximal third of the bone has occasionally poor circulation. According to Talmel & Kelly (1966) the radiocarpal group of vessels are most important for the circulation of the scaphoid and in one case only (1/11 human specimens) a proximal vessel was found leading to the proximal surface of the scaphoid.

Even in children non-union is possible, especially in neglected wrist fractures (Müssbichler 1961, Southcott & Rivers 1977). In our series non-union could be observed in three neglected cases where cystic resorption of the bone was observed but fusion was achieved with conservative treatment.

We suggest that an immobilization time of 3–4 weeks in a plaster splint is sufficient for avulsion and incomplete fissure types of fractures. In transverse fractures the distal plaster cast from below the elbow to the interphalangeal joint of the thumb is at 7

for 4 to 8 weeks. In neglected cases or in

sary

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IMMOBILIZATION AFTER PRIMARY DISLOCATION OF THE SHOULDER

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A total of 226 patients with primary shoulder dislocation were followed up for 1 year, the primary object being to observe the effect of immobilization on the incidence of redislocation. The shoulders were immobilized in a mitella for 1 week in all the 127 patients older than 50 years of age, and in 53 of the patients under 50 years of age. The shoulders of the remaining 46 patients (under 50 years) were completely immobilized with a stockinette-Gulchrest bandage for a period of 3 weeks.

Thirteen per cent (30/226) suffered from one to four redislocations each during the follow up period. Because most recurrences occurred in the

for 1 week, presented a higher frequency of redislocation than the remaining 27 patients subjected to 3 weeks' immobilization ($P < 0.05$). Manual labourers experienced more numerous redislocations than office workers ($P < 0.01$). The greater the initial trauma to the shoulder, the lower was the incidence of recurrence. There were only two among the 57 patients with early complications of the primary shoulder dislocation who had a redislocation ($P < 0.001$). Residual stiffness was encountered more often in the patients over 30 years than in the younger ones ($P < 0.001$).

Following primary shoulder dislocation, 1 week's immobilization in a sling is sufficient in patients over 30 years, while in the case of most of the younger patients 3 weeks' complete immobilization of the shoulder is recommended.

Key words: shoulder dislocation, immobilization

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The mechanism which centres the humeral head in the glenoid cavity may be deficient by laxity or damaged by trauma. Primary and recurrent dislocations occur most frequently in those doing manual labour. The typical patient who presents a history of a recent dislocation is a young man of athletic habits in his second or third decade of life (Moseley 1961). The greater the initial trauma to the shoulder, the higher is the complication rate (Pasila et al. 1978), and the

incidence of recurrence seems to be reduced accordingly (McLaughlin & MacLellan 1967, Pasila et al. 1980, Rowe & Sakellariades 1961). A second dislocation occurred in 42 per cent in a series of 324 primary dislocations described by Rowe & Sakellariades (1961), redislocations occurred in 94 per cent of patients below 20 years, and in 14 per cent of those over the age of 40 years (Rowe & Sakellariades 1961). Of the first redislocations, 64-85 per cent ensued within 1 year in the

series reported by McLaughlin & MacLellan (1967) and Moseley (1961) and in Rowe's series (1956) there were 70 per cent redislocations within 2 years. According to Moseley (1961), Hippocrates stressed the value of immobilization in cases where pain and inflammatory tension did not prevent the use of the shoulder.

Immobilization periods of a few days (Apley 1977, Gjores & Nilsson 1965, London 1971, Turek 1977), 3 weeks (Bateman 1955, DePalma 1970, Rokkanen et al 1975, Rowe & Sakellariades 1961, Wilson 1977) and up to 6 weeks have been recommended (Neer & Welsh 1977, Watson Jones 1948). However, Rowe & Sakellariades (1961) found no convincing evidence in favour of immobilization periods longer than 3 weeks.

The effects of 1 week's partial and of 3 weeks' complete immobilization on primary shoulder dislocations were compared in a prospective study of 1 year's duration.

PATIENTS AND METHODS

In the Department of Orthopaedics and Traumatology, University Central Hospital Helsinki, Finland 226 patients with primary shoulder dislocations were each followed up by one investigator for 1 year during the period September 1st 1973–December 31st 1977. Initially the patients visited the Department of Physical Medicine weekly and later at intervals implied by the treatment. There were 126 men and 100 women, 127 (56 per cent) were older than 50 years. Ninety seven were manual labourers, 45 office workers, 71 in retirement and 13 were students.

No patients with fractures visible on routine X ray projections were included in this study. Axillary nerve and plexus lesions were diagnosed by the localization of paretic muscles and defects of skin sensitivity. Diagnosis of rotator cuff rupture was postponed a few weeks; it was only made in rotator cuff perforations presenting a persistent clinical picture (Pasula et al 1978).

Fifty seven patients (25 per cent) presented a total of 70 complications: 25 were plexus lesions, 19 axillary nerve lesions and 26 rotator cuff ruptures. A single lesion was observed in 45 shoulders, whereas 12 shoulders presented more

There were no patients with multiple and the mechanism of trauma to the shoulder accurately determined in 142 primary dislocations. Falling from a height (15/142) represented most severe and a torsion injury (35/142) least severe dislocation mechanism. Twenty primary dislocations had been incurred while participating in sports activities. Eighteen shoulders were reduced within 1 hour after location, the 'non reduced period' being 1 hour in 81 patients, 3–12 hours in 44 and 12 hours in 14.

Because it was doubtful whether the shoulder of the patients over 50 years could tolerate immobilization for 3 weeks, the shoulders of the 127 patients older than 50 years were immobilized for 1 week in a mitella. Of the patients under 50 years 53 had their shoulders similarly immobilized for 1 week in a mitella. The shoulders of the remaining 46 patients under 50 years were completely immobilized for 3 weeks with a stockinette-Gilchrist bandage (Gilchrist 1967) which was changed weekly. At the termination of the period of immobilization, the patients were encouraged to use the shoulder and the same physiotherapist who changed the stockinette-Gilchrist bandages supervised the mobilization if there were any difficulties. The patients were followed up for 1 year. In assessing the results the age, activity and disability of the patients, the severity of the initial trauma and the complications caused by it (to the shoulder), as well as the duration of the 'non-reduced period' and the first redislocation were taken into consideration. The results were analysed and tested by the χ^2 test.

RESULTS

Thirteen per cent (30/226) of the patients, i.e., 23 men and 7 women, experienced one or more redislocations during the follow-up period. The first redislocations were evenly distributed over the follow-up year, the earliest two of them occurring during the mitella immobilization.

The disposition to redislocation was higher in the patients under 30 years ($P < 0.05$) compared with the older patients.

Table 1 First redislocation, occurring after primary dislocations immobilized for 1 or 3 weeks, in the different age groups

Age groups (years)	Number of first redislocations after the primary immobilization for		Number of primary dislocations	First redislocations/primary dislocations (per cent)
	1 week	3 weeks		
<20	6	4	18	56
20-30	7	2	35	26
30-40	1	1	30	7
40-50	0	1	16	6
50-60	4	—	49	8
60-70	3	—	54	6
70-80	1	—	20	5
>80	0	—	4	0
Total	22	8	226	13

position remained within the same limits in the higher age groups (Table 1)

Of the 53 patients under 30 years (44 men and 9 women), 26 were immobilized for 1 and 27 for 3 weeks. Thirty-six per cent (19/53) of the first redislocations (in 18 men and one woman) were seen in these 53 young patients. Fifty-six per cent (13/26) in the group immobilized for 1 week suffered from a redislocation, whereas this occurred in only 19 per cent (6/26) of the patients immobilized for 3 weeks ($P < 0.05$)

Manual labourers had more redislocations than office workers ($P < 0.01$) (Table 2). The students, all of them under 30 years, had more redislocations than the other patients ($P < 0.001$)

The shoulders primarily easily dislocated by torsion were most frequently redislocated (Table 3). There was a statistically significant difference when these shoulders were compared with the shoulders dislocated in connection with falling on the same level ($P < 0.05$) or falling from a height ($P < 0.01$). However, there was no statistically significant difference between the recurrences in shoulders dislocated in connection with falling on the same level and those dislocated by falling from a height.

The recurrence rate was 17 per cent (28/169) in the shoulders without complications and 4 per cent (2/57) in the shoulders with complications ($P < 0.001$). Two men, both under 20 years and suffering

Table 2 First redislocations divided according to the patients' social groups

Social group	Number of first redislocations	Number of primary dislocations	First redislocations/primary dislocations (per cent)
Student	7	13	54
Manual labourer	17	97	18
Retired	5	71	7
Office worker	1	45	2
Total	30	226	13

Table 3 First redislocations after the various mechanisms of the primary dislocation

Mechanism of primary trauma	Number of first redislocations	Number of primary dislocations	First red. after primary dislocation (per cent)
Fall from a height	0	15	0
Fall in the same plane	9	92	10
Torsion	11	35	31
Total	20	142	14

Table 4 The median duration of sick leave

Age (years)	Number of working patients	Duration of immobilization (weeks)	Median period of sick leave (weeks)
< 50	44	1	2.1
< 50	40	3	3.8
> 50	58	1	3.9

from a transient axillary lesion, experienced a redislocation after recovery from the nerve lesion. In 42 shoulders with some degree of residual stiffness no redislocations were encountered. Among 154 shoulders in patients over 30 years of age, immobilized for 1 week, 26 per cent (40/154) suffered from residual stiffness at the final follow-up. On the other hand, the shoulders of 26 patients under 30 years of age immobilized for 1 week resumed their normal range of motion in all cases but one (4 per cent) ($P < 0.001$).

The difference between the median number of days on sick leave (Table 4) in the two immobilization groups of patients younger than 50 years is statistically significant ($P < 0.01$), as is that between the groups with 1 week's immobilization of patients under and over 50 years, respectively ($P < 0.01$).

DISCUSSION

One year is considered a satisfactory follow-up period since most redislocations occur within 1 year (McLaughlin & MacLellan 1967, Moseley 1961). The frequency of

recurrences was 13 per cent (30/226) in this study. Even better results, however, without any redislocations whatsoever have been reported in extensive personal series both with shorter (London 1971) and longer (Nor & Welsh 1977, Watson-Jones 1948) periods of immobilization.

The longer follow-up, up to 10 years, in the series of Rowe & Sakellariades (1961) provides an explanation for their observation that nerve injuries did not affect the frequency of recurrence. The two recurrences observed in the 44 nerve injuries in the present study occurred after recovery from the axillary nerve injury.

The less the energy required to cause the primary dislocation the more liable was the shoulder to redislocate during the follow-up (Table 3). The earliest mobility recovery was seen in the shoulders easily dislocated by torsion whereas the shoulders dislocated by the most severe mechanism, by falling from a height, took the longest time to resume mobility (Pasila et al. 1980). The frequency of complications was highest among the shoulders dislocated in connection with falling from a height (Pasila et al. 1979) and 10 of the 13 working patients (77 per cent)

group needed a longer sick leave period (more than 1 month) compared with the 166 patients (35 per cent) who fell on the same level or with the 4/24 patients (17 per cent) whose shoulders were dislocated by a fall from a height.

Despite there being many factors with regard to the incidence of redislocation, age seemed to be the most important single factor. The 24 shoulders dislocated while participating in sports activities were more prone to redislocations, 33 per cent (8/24) dislocated but these patients were all under 30 years of age. Furthermore 20/35 (57 per cent) of the patients whose primary dislocation was caused by a torsion injury were under 30 years of age compared with 16/92 patients (17 per cent) sustaining the primary dislocation in connection with falling on the same level and 3/15 patients (20 per cent) who fell from a height.

Patients under 50 years can be safely immobilized with a stockinette-Gilchrist bandage maintained for 3 weeks (Pasila et al 1980), but immobilization in order to prevent redislocations is only important in patients under 30 years of age, as is also prevention of shoulder pain and stiffness only applicable in older patients (McLaughlin & MacLellan 1967). A low incidence of redislocation in the shoulders subjected to considerable initial trauma was also observed by Rowe & Skellardes (1961) and by McLaughlin & MacLellan (1967) in shoulders with complications conforming with the results in this study. Some young patients with hypermobile joints give a history of instability of the shoulder prior to the primary dislocation and it is doubtful whether prolonged immobilization is indicated in shoulders such as these. Following primary shoulder dislocation, 1 week's immobilization in a sling is sufficient in patients over 30 years, but in most of the younger patients 3 weeks' complete immobilization of the shoulder is recommended.

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PULMONARY EMBOLIC SYNDROME CAUSED BY CEMENTING OF HIP ENDOPROSTHESIS

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Previous studies have indicated that cementing of the femoral component in total hip replacement produces the features of the pulmonary embolic syndrome (PES). The present investigations have been carried out to ascertain if newer methods of insertion modify these features.

There was no evidence to suggest that any of these approaches has any advantage over the others in relation to the various components of PES.

Key words: arthroplasty, bone cement, pulmonary embolic syndrome, venting

Accepted 6 v 80

In a previous communication by Alexander & Barron (1979) it was established that the insertion of methyl methacrylate and a prosthesis into the femoral marrow cavity results in the pulmonary embolic syndrome (PES). This condition is characterized by a relative hypoxaemia, elevation of serum lipase accompanied by a fall in triglycerides and the development of anaemia.

Attempts have been made to prevent or modify this syndrome, either by the method of venting carried out by the surgeon or by the use of intravenous alcohol as described by Alexander & Barron (1980). Studies with intramedullary pressures by Tronzo et al (1974) and by Barron (1979) have shown that intramedullary hypertension is a feature of the insertion of both cement and prosthesis. While acrylic pressures can be modified by the method of venting, prosthetic pressure is unaffected and may be more than 600 mmHg. It is considered that the hypertension is responsible for the intravasation of medullary contents which produce PES.

PATIENTS AND METHODS

The present investigations have been carried out to examine the effects of using a cement gun (Howmedica) as outlined by Lee et al. (1978) to introduce the cement into the marrow cavity, and of blocking off the lower half of the cavity by means of either a bone block (Wroblewski 1979) or a plug of cement (Indong et al. 1978). Twenty patients were involved in each of the three methods.

Patients were not selected and the method used was the choice of each individual surgeon. Venous and arterial samples were obtained as described previously by Alexander & Barron (1979) except that in patients having bone or cement blocks additional arterial samples were taken before and after their insertion.

RESULTS

Blood gas analyses showing arterial oxygen values are presented in Table 1 while serum triglyceride and lipase values are shown in Tables 2 and 3. It can be seen that these follow very closely the results obtained in

Table 1 Arterial oxygen tension values at various stages of the operation
Arterial Oxygen

	Before block	After block	Before cement and prosthesis	After cement and prosthesis	P _{O₂}
Cement gun	—	—	15.18 ± 5.04	14.01 ± 4.41	18
Bone block	16.77 ± 2.58	17.10 ± 4.05	16.11 ± 4.35	13.86 ± 2.98	23
Cement block	16.38 ± 3.89	17.90 ± 4.02	17.16 ± 5.78	14.92 ± 3.56	21

Table 2 Serum triglyceride values obtained with the three alternative methods
Triglycerides

	Control	4 hours	24 hours	4 days
Cement gun	1.29 ± 0.50	0.97 ± 0.33	0.92 ± 0.23	1.09 ± 0.41
Bone block	0.96 ± 0.41	0.58 ± 0.32	0.74 ± 0.31	1.07 ± 0.41
Cement block	1.06 ± 0.36	0.56 ± 0.31	0.63 ± 0.28	0.94 ± 0.41

Table 3 Serum lipase values obtained with the three alternative methods
Lipase

	Control	4 hours	24 hours	4 days
Cement gun	1.01 ± 0.41	1.30 ± 0.51	1.17 ± 0.44	1.10 ± 0.41
Bone block	0.84 ± 0.37	1.35 ± 0.50	1.13 ± 0.43	0.68 ± 0.41
Cement block	0.92 ± 0.38	1.30 ± 0.51	1.41 ± 0.43	1.01 ± 0.41

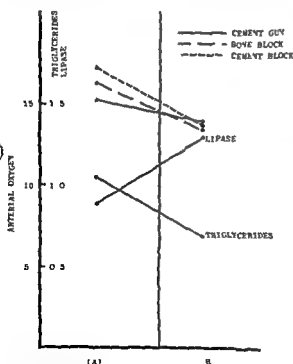


Figure 1 Arterial oxygen triglyceride and lipase values —

(A) before insertion of cement and prosthesis, and
(B) after insertion

previous studies using drill hole or reaming and venting or when intravenous alcohol employed as described by Alexander and Barron (1980). The results are presented graphically in Figure 1.

DISCUSSION

Attempts to modify PES by the use of cement have been mainly concerned with the use of venting. These have included the use of a plastic catheter, the drilling of a hole in the proximal junction of the upper one-third and the middle two-thirds of the femoral shaft, the use of a plug of the methacrylate by means of a cement gun and the blocking of the distal base of the marrow cavity with a plug of either bone or cement. It should be said that the main objective has been to obtain a functional prosthesis rather than the prophylactic use of cement. The only attempt at modification of the anaesthetic concerns the use of intravenous alcohol.

It would appear from the results of the present study that the most recently induced surgical manoeuvres do not prevent modify P.E.S. This is not surprising since they in no way affect the final intramedullary hypertension produced by the nmering into position of the femoral pro-

sis.

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OSTEOARTHRITIS OF THE HIP AND KNEE JOINT IN RETIRED FOOTBALL PLAYERS

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The possible relationship between football playing and osteoarthritis in the hip and knee joints has been examined. The results of clinical and radiographic examinations of 57 retired football players and a corresponding control group were compared. Osteoarthritis of the hip joint was found to occur significantly more often in the football players than in the controls. Such a relationship could not be found regarding the knee joint.

Key words: football, hip joint, knee joint, osteoarthritis

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Several studies have been made to investigate the ill-effects of sports on the kinetic system (Jarvaho & Langfeldt 1977, Heiss 1929, Lurien et al. 1975). Baetzner (1936) was one of the first to notice the frequent occurrence of degenerative joint changes in top athletes.

Football is probably the most popular ball game in the world, and as such is played by a considerable number of young men. It is, therefore, natural that there has been a growing interest in the possible relation between the development of osteoarthritis in the lower extremities and football playing. In several studies have been published on this subject (Brodellus 1961, Köhler 1955, Solonen 1966, Thorseth 1972). These investigations demonstrated a greater prevalence of osteoarthritic changes in the ankles of football players (Brodellus 1961, Köhler 1955, Solonen 1966), but not in the hip and knee joints (Köhler 1955, Solonen 1966). As a result of the introduction of professional football in Denmark, we found it of interest to re-examine these results. The purpose of this study was to elucidate a possible relationship between top-level football playing over many years and the prevalence of osteoarthritis in the hip and knee joints.

PATIENTS AND METHODS

In cooperation with Vejle football club's secretariat, 62 previously active football players were randomly selected, and 57 agreed to participate in the study. Radiographs of the hip and knee joints were taken and a clinical examination was made. The following information was recorded: age, weight, average number of playing hours per week during the period of activity, the length of the period of sporting activity, occupation, injuries requiring treatment as well as surgery to the lower extremities.

Thereafter, a control group was formed of 57 men admitted to the local hospital for complaints other than neurological and not for problems in the lower extremities. These men had never been active football players. Each person in the control group matched one of the football players with regard to age (± 2 years) and weight (± 5 kg) and all were examined clinically and radiographically, in the same way as the football players.

The radiographic examination used the hospital's routine source-to-film distance of 1 metre. The hip joints were radiographed in the supine position with one film registering the pelvis and both hip joints. The knee joints were radiographed in A-P and lateral projections. The X-rays were all made in the recumbent position, which is the routine in the department, and therefore only distinct changes of osteoarthritis are included in the material.

The radiographs were evaluated by a qualified

radiologist Radiographic signs of osteoarthritis which were accepted were diminution of the joint space, sclerosis and/or subchondral cyst formation. In this way, those whose only sign of change was osteophyte formation were eliminated. The rationale for this was that in previous studies, the relationship between osteophyte development and the subsequent occurrence of osteoarthritis could not be confirmed (Danielsson 1964).

The χ^2 test was used to evaluate statistical significance.

RESULTS

The 57 football players had an average age of 56.4 years (40–79), their average weight was 78.5 kg (61–104), the average number of playing hours per week in the period of activity was 6.7 (3–10), and the average period of activity was 22.8 years (11–41). In the control group, the corresponding values were 56.6 years of age (42–80) and 78.1 kg body weight (61–104).

Among the football players, positive signs of osteoarthritis were seen in 30 (52.7 per cent), while the same changes were seen in 19 (33.3 per cent) of the men in the control group. This difference is statistically significant ($P < 0.05$). Twenty-eight (49.1 per cent) of

the 57 retired football players demonstrated positive signs of osteoarthritis in the hip joint. The same changes were seen in only 15 (26.3 per cent) of the 57 controls. This difference is statistically significant ($P < 0.05$). There was no difference regarding the knee joints as osteoarthritis was found in eight previous football players and in seven of the controls.

The localization of the osteoarthritic changes is shown in Table 1. The average age of the 30 football players with radiographic signs of osteoarthritis was 59.5 years and the 19 in the control group, 60.2 years. Of 49 individuals with radiographic osteoarthritis, seven presented subacute symptoms. Thirteen football players and three of the control group with osteoarthritis had suffered previous trauma to the lower extremities (see Table 2).

Five of the thirteen football players sustained injuries to the meniscus, four of which had been treated conservatively. One player had been meniscectomized in both knees and had osteoarthritis in both. The other four players suffered from bilateral hip joint osteoarthritis, and two of these presented osteoarthritic changes in the injured knee.

Of the 30 football players with osteoarthritis

Table 1 Localisation of radiographically distinct osteoarthritis in 30 football players and 19 controls

	Hip joint		Femoro-tibial joint		Femoro-patellar joint	
	Unilat.	Bilat.	Unilat.	Bilat.	Unilat.	Bilat.
Football players	9	19	4	1	2	4
Control group	3	12	1	4	0	1

Table 2 Number and type of injuries to 13 football players and 3 controls with radiographically verified osteoarthritis

	Football players	Control group
Fracture	3	1
Meniscus lesion	6	2
Other*	7	0

* Distortion, ligament injuries, ruptured tendons, etc.

hritis, 8 (26.7 per cent) were doing jobs involving heavy physical labour, while of the in the control group, there were 9 (47.4 per cent) doing similar heavy jobs.

DISCUSSION

The aetiology of osteoarthritis is as yet poorly defined. The disease apparently results from a combination of factors, such as age, endocrine balance, injury as well as mechanical strain (Isdale 1975, Jurmain 1977). This study demonstrated a significantly higher prevalence of osteoarthritis among retired football players, as compared with a control group. As seen in Table 1, the difference between the groups lies in the frequency of osteoarthritic changes in the hip joint, while the occurrence of changes in the knee joint is rather similar. This finding agrees with Thorseth (1972) who studied the knee joints of 208 retired top football players. The hip joint was not examined. In contrast, the present study did not agree with the findings of Köhler (1955) or Solonen (1966), who found no correlation between football playing and osteoarthritis of the hip joint. A possible explanation could be that the average age in the above studies was 24.5 and 26.0 years, respectively. Moreover, the material from both studies is incomplete, as radiographs were taken of only some of the players examined.

Previous investigations (Puranen et al. 1975, Carvalho & Langfeldt 1977) have shown that the frequency of osteoarthritic changes is not increased by running. The fact that we found an increase in the prevalence of osteoarthritic changes among previous football players could be explained by the fact that running is a physiologic activity while football often involves excess strain on the

lower extremities in the form of non-physiologic attitudes and numerous injuries.

It is concluded that after many years participation in top level football the prevalence of osteoarthritis of the hip joint, but not of the knee, is increased.

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TOTAL HIP REPLACEMENT *AD MODUM* RING

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A 2-9 yr follow-up of 309 patients operated on with the Ring total hip replacement prosthesis. The results were compared with those of the Charnley prosthesis. The mortality rate was 0.3 per cent. Early deep infection occurred in 0.7 per cent and late deep infection in 0.3 per cent, 4.4 per cent needed revision for aseptic loosening. The results were significantly poorer when the short prosthesis was used. Even apart from those reoperated on the results were significantly poorer when the short prosthesis was used.

It is concluded that the Ring prosthesis can still be recommended, but that the long prosthesis should be used whenever possible. When this is not possible, a cemented prosthesis should, perhaps, be used.

Key words: hip joint, metal-to-metal prosthesis, Ring total arthroplasty

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In 1968 Ring introduced a total hip replacement in which both replacement components were made of metal, and where no cement was used in the fixation (Ring 1968). Since 1968 this method has been used at the Department of Orthopaedic Surgery, Kolding. Our preliminary results, together with the results of 10 other orthopaedic surgery departments have been published previously (Paaby 1974). Our preliminary findings indicate that this method gives results that are as satisfactory as those achieved by cemented prostheses. It has been put forward by Evarts et al. (1972) that the Ring prosthesis has a significant tendency to work loose with a detrimental effect on the original result. Apart from Ring's own findings (1968, 1970, 1971, 1973, 1974) there are no other reports with an acceptable number of patients and a reasonable observation time, so we

have reviewed all our patients operated during the period 1968-1976, with the intention of evaluating the results after a minimum follow-up period of 2 years.

PATIENTS AND METHODS

During the period 1968-1976, 309 patients were treated with a total hip replacement *ad modum* Ring. At the time of the follow-up 111 had died, and 19 did not attend. There were therefore 252 patients of whom 43 had been operated on bilaterally. A total of 295 operated hips were therefore included in the study.

Sex and age distribution are shown in Figure 1, the average age was 66 years (range 35-81 years).

Operative indication was pain and impaired function combined with clinical and radiographical signs of irreversible hip disease. The preoperative diagnosis is shown in Table 1. In 78 per cent of the cases the indication for operation was

Number of operations

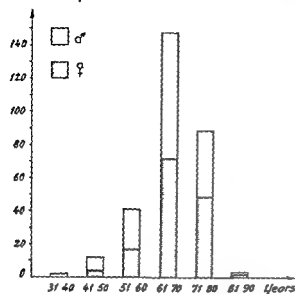


Figure 1 Sex and age distribution at operation

arthritis. Thirty-one patients had been operated on previously (osteotomy 13, nailing of fracture of the neck of the femur 9, femoral head replacement 6, other procedures 3).

The operations had been performed in a conventional operating theatre mainly as the first operation of the day and most often on the day after admission. The operative technique was as described by Ring (1968, 1970, 1974). Prophylactic antibiotic treatment with penicillin was given until the removal of the sutures. One of the surgeons has also given streptomycin for 5 days (63 operations). The patients were given prophylactic anti-coagulation treatment with Phenprocoumon (Marcoumar®) from the day before the operation until discharge. After the operation skin traction (2 kg) was applied for 7 days in all patients. After this they were mobilized with two elbow crutches. They were allowed to bear weight on the operated hip and were advised to use elbow crutches until the first follow up examination 2-3 months after the operation. The patients were discharged when they could manage alone and were able to negotiate stairs. At the follow-up the results were evaluated using the Merle D'Aubigné classification as modified by Charnley (Merle D'Aubigné & Postel 1954, Charnley 1972). The construction of the scale is shown in Table 2.

RESULTS

The average observation period was 5.4 years (range 2-10 years). In Figures 2, 3 and 4, the

pre- and postoperative results of pain, movement, and walking are given in points. Sixteen of the 100 were excluded as these had been reoperated on at the time of the follow up leaving 84 patients. The average number of points for pain was 14 preoperatively and 5.4 postoperatively. Fifty-seven per cent became completely free of pain, whereas 27 per cent had intermittent pain, in most cases taking only a few drops of slight pain on starting to move. The average preoperative points for movement were 10 compared with 5.0 postoperatively. 69 per cent achieved a range of flexion of 90 degrees or more. The average postoperative points for walking ability were 2.2 compared with 1.0 preoperatively. The average patient was able to walk for longer distances. Thirty-six of the patients did not use sticks at all.

Complications

The local complications are shown in Table 3. One per cent had a superficial infection that did not affect the prosthesis. A deep infection occurred in two cases. The prostheses were removed and the patient given Girdlestone hips. There was one late deep infection, with increasing pain 2 years after the operation. Infection showed the growth of non-haemolytic streptococci. After 3 months of antibiotic treatment the prosthesis was removed. A Lubinus prosthesis fixed with cement containing gentamicin was used instead. There was no sign of infection a year later.

One prosthesis dislocated immediately after the operation and was treated by

Table 1 Preoperative diagnosis

Diagnosis	No. of cases
Primary osteoarthritis	211
Post traumatic osteoarthritis	25
Rheumatoid arthritis	1
Anchylous spondylitis	3
Miscellaneous	1
Total	241

Table 2 The evaluation of pain movement and walking ability according to Charnley (1972)

Pain	Movement	Walking
Severe and spontaneous	1 0-30 degrees.	1 Few yards or bedridden. Two sticks or crutches.
Severe on attempting to walk Prevents all activity	2 31-60 degrees.	2 Time and distance very limited with or without sticks.
Tolerable permitting limited activity	3 61-100 degrees.	3 Limited with one stick (less than 1 hour) Difficult without a stick Able to stand long periods.
Only after some activity Disappears quickly with rest	4 101-160 degrees.	4 Long distances with one stick. Limited without a stick.
Slight or intermittent. Pain on starting to walk but getting less with normal activity	5 161-210 degrees.	5 No stick but a limp
No pain	6 211-260 degrees.	6 Normal

uction there has been no dislocation
ce In three cases a break appeared in the
tw of the acetabular component of the
ly design of prosthesis with a slim stem
one case the prosthesis had to be replaced
rtabular components with a conical screw
e been used since 1974

The roentgenograms at the time of the
low up showed among 279 non reoperated
s, 118 cases with radiolucent zones sur-
rounding the femoral component (42 per
nt) In 20 cases the zone was at least 3 mm
de (7 per cent) The prosthesis had settled

into the femur in 37 cases (12 per cent)
Fifty seven acetabular components were
found to have radiolucent zones (20 per cent)
measuring at least 3 mm in 13 cases (5 per
cent). Increased density in the bone structure
surrounding the acetabular screw was found
in 142 prostheses (51 per cent) In 104 pros-
theses no radiolucent zones were found
(1 mm or less)

In 18 cases considerable ectopic bone
formation was found surrounding the pros-
thesis evident as a bridging of the prosthesis
cranially and/or caudally

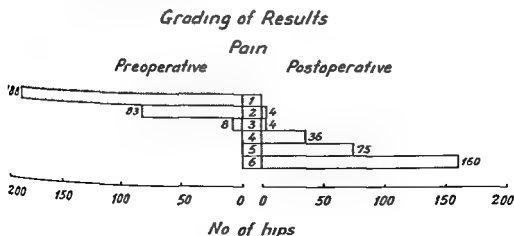


Figure 2 Grading of pain according to Charnley (1972)

Grading of Results

Movement

Preoperative

Postoperative

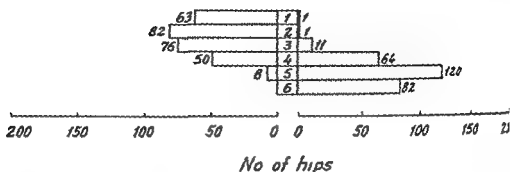


Figure 3 Grading of movement according to Charnley (1972).

One patient died 4 hours after the operation as a result of haemorrhage from the iliac vein caused by the acetabular screw. There were no other mortalities during hospitalization. Eleven patients contracted deep vein thrombosis. Two patients had minor pulmonary embolisms.

Twenty-five per cent were actively employed preoperatively, although all were disabled to some extent, and many had been unfit for work for long periods. Twenty-four per cent were receiving disablement pensions, and 51 per cent were old-age pensioners. At

the time of the follow-up 12 per cent were actively employed. Two patients, however, changed to less physically demanding work. Twenty per cent were receiving disablement pensions, and 61 per cent old-age pensions.

DISCUSSION

In Table 4 our results are compared with those of others. Mossing & Holm (1977) and Lindholm & Puranen (1976) used 1-

Grading of Results

Walking

Preoperative

Postoperative

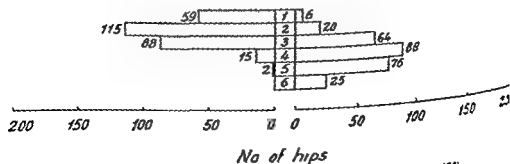


Figure 4 Grading of walking ability according to Charnley (1972).

Table 3 Local complications after 295 total hip replacements *ad modum* Ring

	Number of hips	Per cent
surface infection	3	1.0
deep infection	2	0.7
deep infection	1	0.3
osteomyelitis	1	0.3
joint failure	3	1.0
loosening requiring revision	12	4.1

D'Aubigné's method of classification, while in other results Charnley's modification of the D'Aubigné's scale has been used. The age result in our material, to the nearest year, was identical using either method of classification. It is therefore possible to compare results with all of the others. Our results are similar to those achieved using the Charnley and the Charnley prosthesis. Charnley has excluded those patients with systemic diseases affecting gait. Ring (1974), in a follow-up after 1-5 years of 535 hips operated with the present type of prosthesis, obtained 'excellent' and 'good' results in 90 per cent of the cases. Our results show 87 per cent 'excellent' and 'good', and therefore they agree with Ring's.

The complication frequency is another method of evaluation. The infection rate in our results (1 per cent) agrees with Ring's (1 per cent). Fitzgerald et al (1977) found,

after a follow-up period of 2-5 years, an infection rate of 1.3 per cent among 3210 hips operated *ad modum* Charnley and in the report of Dandy & Theodorou (1975) the comparable figures were minimum follow-up 2 years, infection rate, 1.6 per cent, hips, 1042 operated *ad modum* McKee-Farrar.

With an infection rate of 1 per cent we do not consider it necessary to alter the present prophylactic antibiotic treatment with penicillin. We will also continue to use a standard operating theatre, without the use of a 'green house' or similar precautions.

The mortality rate was 0.3 per cent. We consider the prophylactic anticoagulant treatment responsible for the fact that there were no fatal cases of thromboembolism.

Loosening is a considerable problem in all types of prostheses. Dandy & Theodorou (1975) found 6.6 per cent had been revised because of loosening in 1042 McKee-Farrar

Table 4 Comparative results

	Charnley (1972)	Patterson & Brown (1972)	Mossing & Holm (1979)	Visuri et al (1977)	Lindholm & Puranen (1976)	Own results (1979)
Prosthesis	Charnley	McKee-Farrar	Stanmore	Brunswick	Ring	Ring
Number of replacements	379 ^a	368 ^a	205 ^a	185 ^a	40 ^a	279 ^a
Reoperation	5.9	4.5	5.9	5.4	4.1	5.4
Dislocation	5.2	4.2	5.5	4.8	4.2	5.0
Loosening	5.9	3.4	4.6	4.6	3.7	4.0

^a Evaluated according to Merle D'Aubigné & Posel (1954)

^b Evaluated according to Charnley (1972)

prostheses with a minimum follow up of 2 years. Ring (1974) found loosening that required revision in 37 per cent of 942 hips fitted with the Ring prosthesis. In another 535 hips also with Ring's prosthesis, he found 2 per cent that required revision after a minimum follow up of 1 year.

In our material 41 per cent were revised because of loosening. In one case the loosening was caused by osteoporosis due to high voltage radiation for a bladder cancer. In nine cases it was the short femoral component that had loosened. These were all replaced by long femoral components. Three short prostheses were in functionally poor positions due to previously performed displacement osteotomies, with a displacement of approximately 2 cm. In our material 35 per cent were fitted with the short femoral components. We did not, perhaps, put enough emphasis on using the largest possible prosthesis. The bone marrow cavity was therefore not adequately filled by the prosthesis. The results are clearly less satisfactory when the short prostheses were used, 86 per cent of these were revised because of loosening compared with only 1 per cent of the long prostheses. There are also, apart from the reoperated patients, significantly poorer results in the cases where the short compared with the long (χ^2 test $P=0.05$) prosthesis was used. Among 184 long prostheses there were 119 'excellent', compared with 48 'excellent' among 95 short prostheses.

Among the non reoperated prostheses there was no significant difference in the results of the patients who had radiolucent zones of at least 3 mm surrounding the prosthesis, and those who had none. Patients with ectopic ossification around the prosthesis had, as expected, a significantly poorer range of movement (χ^2 test $P=0.05$). As also found by Ring (1974) it was characteristic that ectopic ossification was most evident within the first 6 months, and then remained largely unchanged. Two patients who had been operated on bilaterally had an equal amount of ectopic ossification on both sides. It is therefore reasonable to suppose as did Ring

that ectopic ossification is dependent on constitutional conditions. We have, in one case, attempted to remove ectopic bone surgery, but the long term result was doubtful.

Only 12 per cent of the patients were actively employed at the time of the follow up. Considering that the average age of the patients at this stage was 71 years, this is so surprising. Willcock (1978), in a prospective investigation of 49 patients operated *ad modum* Charnley, has shown the greatest advantage of total hip replacement in elderly people apart from the fact that a great number of patients became patients that they are more capable of carrying out daily tasks. It was concluded that total hip replacement contributed to an improvement in quality of life of the patients and to the demand for community health and welfare services.

CONCLUSIONS

The Ring prosthesis can still be recommended. The results when using the short prosthesis are clearly less satisfactory. Therefore the long prosthesis should be used where possible. In the cases where this can not be done a cemented type of prosthesis should be used. Using these guidelines the results are not unlike those achieved with cemented prostheses as far as the frequency of loosening requiring revision is concerned (Dach Theodorou 1975, Nolan et al. 1977).

The great advantage of this method is the relative ease with which the prosthesis can be changed whether because of loosening or infection. The opposite is the case with a cemented prosthesis.

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FUNCTION OF FIFTY-SEVEN SEPTIC, REVISED AND RE-REPLACED TOTAL HIP ARTHROPLASTIES

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An evaluation of hip function was made 2-5 years postoperatively in 57 patients reoperated using gentamicin-containing bone cement because of deep infection after total hip arthroplasty. Forty patients were completely free from pain and 17 had slight intermittent pain. Fifty-one had normal or nearly normal walking ability. Most patients managed dressing and getting in and out of a bath without help. It is concluded that revision in most cases offers a satisfactory solution for the patient and gives a better functional result than simple removal of the prosthesis.

Key words: hip joint, arthroplasty, gentamicin

Accepted 26 iv 80

The discussion regarding infected total hip arthroplasties has until quite recently been focused mainly on cure of the infection. Many orthopaedic surgeons have advocated definitive removal of the prosthesis as the best method of treatment (Hunter & Dandy 1977, Ahlgren et al 1980). It has now been shown, however, that good results with 70-80 per cent healing of the infection can be achieved by revision operations using gentamicin-containing bone cement and re-insertion of the prosthesis (Buchholz et al 1977, Carlsson et al 1978, Rottger et al 1979). A survey of the functional rehabilitation of these revision operations is therefore now needed for comparison purposes.

A search of the literature did not reveal any detailed study concerning the function of the hip joint after revision arthroplasties for deep infection whereas several studies of the functional results after removal of the prosthesis have been published during recent years (Patterson & Brown 1972, Haw & Gray

1976, Clegg 1977, Ahlgren et al 1980, Petty 1979).

The purpose of this study was to evaluate the function of the hip joint after successful revision with gentamicin-containing cement in a series of total hip arthroplasties with deep infection.

MATERIAL AND METHODS

This study is part of a more comprehensive in-

method have been reported on in an earlier publication (Carlsson et al 1978). Fifty-two of these 77 hips were included in this investigation. The remaining 25 were excluded, ten because of persistent infection, two owing to elevated erythrocyte sedimentation rate which suggested persistent infection, seven because of new bacteriological criteria for deep infection (Kamme & Lindberg 1980), four because of non-infectious

Table 1 Method of grading functional status of the hip

Grade	Pain	Mobility* (degrees)	Walking ability
1	Severe and spontaneous	0-30°	Bedridden or only able to walk a few meters
2	Severe on attempting to walk, prevents all activity	31-60°	Walking distance very limited with or without a walking aid
3	Tolerable, permits limited activity	61-100°	Limited but able to stand for long periods
4	Present only after activity, disappears quickly with rest	101-160°	Long-distance walking possible without aid
5	Slight or intermittent, decreasing with activity	161-210°	Walks without aids but long
6	No pain	More than 210°	Walks normally for age

* Passive range. Sum of degrees of flexion, rotation, and abduction-adduction.

loosening and two because the patients have died. To the remaining 52 hips were added five infected, revised and healed arthroplasties operated on subsequently in the participating departments. The evaluated series thus consisted of 57 hips in 57 patients where the infection was classified as healed after revision. We use the term "healed", irrespective of the degree of pain, to denote hips in which wounds and sinuses are healed, where there are no radiographic signs of infections and where the sedimentation rate is normal (Carlsson et al 1978).

Twenty-nine of the patients were revised in Lund, 16 in Gävle, and 12 in Malmö. The primary hip arthroplasty was performed because of osteoarthritis in 47 patients, rheumatoid arthritis in four, fracture of the femoral neck in four, ankylosing spondylitis in one and congenital dislocation in one patient. At the revision arthroplasty 29 Brunswik, 14 Christiansen, 9 Charnley and 5 Lubinus prostheses were inserted. Forty-three of the revisions were made in one stage (immediate exchange) and 14 in two stages. The interval between removal and reinsertion in the two-stage cases averaged 12 months (range 1-41 months).

The function of the hip was assessed after 37 months on average (range 24-62 months). The mean age of the patients at the review was 67 years (range 50-80 years).

The hip function was assessed according to the numerical system of Merle d'Aubigné & Postel (1954) as modified by Charnley (1972, 1979). The modification used by Charnley means that the patients are put into three categories. The category A patient is physically fit in all respects relating to function, having no defect other than the one hip affected. In category B patients both hips are affected but the patient is otherwise

physically fit. Category C is reserved for patients with conditions other than diseases of the hip impairing the act of walking such as cardiac insufficiency, rheumatoid arthritis, osteoarthritis of the knee etc. In our series, 27 patients were classified as category A (mean age 66 years), 11 as category B (mean age 69 years) and 19 as category C (mean age 69 years).

The patients were examined by senior and junior physiotherapists without previous knowledge of the patients. The hip function, the walking capacity, the ability to climb stairs, the need for walking aids, shortening of the leg, Trendelenburg's sign were evaluated. The patients were interviewed with regard to activities of daily living and need for special equipment (e.g. raised seats, high toilet seat), estimate of walking distance and subjective opinion of the results of the revision.

FINDINGS

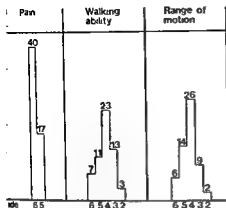
No difference was found between the one-stage and two-stage operations.

The number of patients was too small to make a statistical analysis meaningful.

The findings as regards pain, walking ability and range of motion after the hip arthroplasty are summarized in Figure 1.

Forty patients were completely free of pain. The remaining 17 had either a permanent or intermittent pain decreasing with activity. The average grade for pain was 5.7.

Normal gait was recorded for 7 patients.



number of patients is indicated above the columns

Fig. 1 Assessment of hip function according to the d'Aubigné & Postel (1954)

areas the walking ability was slightly reduced in 34 patients. Sixteen patients had reduced or very limited walking capacity. The average grade for this group was 4.1. The passive range of motion was more than 101 degrees in 46 patients. Two patients had a severely decreased range, less than 60 degrees. The average grade was 4.1.

The category A patients were those best reflecting the hip function after revision operations, whereas in categories B and C the assessment was also influenced by factors other than the operated hip (Table 2).

The walking ability was normal or nearly normal for half of the patients in category A. If of this category also had a walking distance of more than 2 kilometres and two-thirds managed without walking aids or with a stick outdoors.

Twenty six patients had no shortening of the leg, 21 a shortening less than 2 cm and 8 between 2 and 3½ cm. Two patients had a lengthening of between 1 and 2 cm of the operated leg. Seventeen patients walked without a limp and 40 with a limp of varying degree. Twenty three had a positive Trendelenburg sign on the revised side. All patients managed to climb stairs with regular walking aids. Concerning personal dressing 18 patients had no difficulty in putting on trousers or stretch tights, 9 used an appliance

and 10 needed help from another person. Fifty-five patients could put their shoes on unaided with or without an appliance, 2 needed help from another person. Thirty-nine patients managed getting in and out of a bath by themselves. A high toilet seat was needed by 24 patients and a raised seat was used by 22 patients.

The subjective opinion of the result of the operation was very satisfactory in 40 patients and satisfactory in 15. Two patients, both category C, were not satisfied.

DISCUSSION

The natural history of the infected total hip arthroplasty has already been described by many authors (Salvati 1976, Hunter & Dandy 1977, Petty 1979). The outcome is in reality nearly always a loss of hip joint function, due either to removal of the prosthesis or persistent infection. This is the reason why this in-

Table 2 Walking distance (estimated by the patient) need for walking aids and grade of walking ability. The patients are grouped in categories A, B and C (Charnley 1972)

	Number of patients in category		
	A	B	C
Walking distance			
> 2000 m	15	3	0
2000 m - 500 m	10	9	9
500 m - 100 m	2	3	4
< 100 m	0	1	1
No walking aids	12	0	0
1 stick outdoors	6	7	2
1 stick also indoors	8	5	7
2 sticks outdoors	1	1	1
Always 2 sticks or crutches	0	3	4
Ability to walk			
Grade 6	7	0	0
Grade 5	8	3	0
Grade 4	8	8	7
Grade 3	4	4	5
Grade 2	0	1	0

vestigation was confined to revised and healed cases

Andersson (1972) compared nine different methods of assessment of hip joint function and emphasized the importance of uniformity in publishing results. The Merle d'Aubigné-system as modified by Charnley (1972, 1979) is at present probably the one most used. Hence this was the system of grading chosen for this investigation. However, as we wished to present a more detailed report on our cases, we added a few variables.

As this study was not prospective as regards the function of the revision arthroplasties the preoperative gradings were not recorded.

The average grade of pain (5.7), walking (group A 4.7 and B 3.8) and range of movement (4.1) in this series can be compared with the corresponding values reported by Griffith et al (1978) in a series after primary total hip replacements which healed without infection. Their material consisted of 547 hips. The postoperative mean value for pain was 5.8. For walking category A 5.8 and category B 5.4, respectively and for range of movement 4.9. The values in this report after revision arthroplasty are fairly consistent with the values reported by Griffith et al (1978) after uncomplicated, primary total hip replacements as far as pain and range of movement are concerned.

Twenty-eight patients in our series had a shortening of the operated leg. This demonstrated the difficulty involved in achieving full compensation for the destruction of bone often connected with a deep infection. When embarking on a reoperation of this kind the orthopaedic surgeon must have a supply of different prostheses to choose between, in order to achieve the best possible result.

Clegg (1977) and Ahlgren et al (1980) reported the functional results after removal of altogether 57 infected total hip prostheses. It was possible to compare their results with ours as regards some of the findings. Five of their patients used axillary crutches or were

confined to a wheelchair after removal of the prosthesis. This was not observed in any of our patients after revision arthroplasty. In our series 12 patients who had their prostheses removed needed one or two sticks or crutches and had a shortening of the limb of more than 3 cm, in many cases up to 6 cm. In a series of 57 patients, 12 did not use walking aids at all and 26 had no shortening of the leg. A shortening of up to 3 cm was encountered in six cases only. Another variable is the rate of healing of the infection after revision with gentamicin-containing cement. The healing rate in our series (Carlsson 1978) was 78 per cent, when the 12 patients, excluded from this series because of non-infectious loosening, are included among the failures. For removal of the prosthesis the figures are almost the same (Hunter & Dwyer 1977, Clegg 1977, Ahlgren et al 1980).

Petty (1979) discussed the results in patients in which the prostheses had to be removed because of infection. He stated that all but two patients required crutches for walking. One patient was satisfied with the result of her revision arthroplasty. Some authors still recommend that a septic total hip arthroplasty be treated by removal of the prosthesis and an insertion of a new prosthesis should be made only if the functional outcome is satisfactory for the patient (Slooff et al 1977, Ahlgren et al 1980). Other authors (Buchholz & Garton 1977) advocate revision with antibiotic-containing bone cement, preferably using a two-stage procedure. The healing rate of the infection is between 70 to 80 per cent with this procedure (Buchholz et al 1977, Rotinger et al 1977). Certainly there are cases in which removal of the prosthesis is the best solution, for instance in very old patients or those with repeated failed revisions. A two-stage revision (Hovelius & Josefsson 1977) may be preferable in other cases, especially those with widespread deep infection caused by Gram-negative bacteria and/or comprehensive destruction of bone when it

in has failed. At these revisions, the mass is extracted and the wound cavity filled with gentamicin-containing polymethylmethacrylate beads for 3 to 4 weeks. A prosthesis is then inserted, using gentamicin-containing bone cement. In most cases the method of choice is, however, the one-stage revision with gentamicin-containing bone cement, performed at an early stage of the infection. During these operations the functional results will be better than after a removal of the prosthesis.

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ETABULAR PROTRUSION FOLLOWING DOPROSTHETIC HIP SURGERY: MULTIFACTORIAL STUDY

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Acetabular protrusion was found in 56 out of 211 patients fitted with a hemiprostheses. The indication for operation was acute femoral neck fracture or failure following a previous internal fixation. A number of radiological variables were analysed with respect to their possible association with preoperative, operative and follow up variables. After a preliminary screening of variables a deeper analysis was performed by fitting

who now receive a hemiprostheses as a secondary operation. Acetabular protrusion was significantly associated with the development of postoperative pain, while the other clinical symptoms and signs lacked any direct association with protrusion. Although acetabular protrusion and loosening of the prosthetic stem showed a significant association the analysis indicated that pain was primarily due to protrusion.

Key words: acetabular protrusion hip prosthesis

Accepted 13 v 80

Primary prosthetic replacement has become a standard method of treatment for acute femoral neck fractures and is now recognized as the treatment of choice for many authors (Johnson & Crothers 1975, Devas 1976 Whittaker et al 1972).

Acetabular protrusion is a well recognized finding which has been linked to the development of late pain and dysfunction (Arcy & Devas 1976 Andersson & Møller 1972). However, very few authors have presented details concerning the radiological and clinical relevance of the findings.

This study has been performed to answer the following questions 1 Are there pre-operative and operative variables that can be related to protrusion, and if so what is their relative importance? 2 How does increasing follow up time affect protrusion? 3 Can we find some association between the various clinical variables and possibly link them with protrusion?

MATERIAL AND METHODS

The clinical and radiological data of 211 patients who had been fitted with Christiansen's hemiprostheses (Søreide et al. 1975) during the

period 1971-1978 and had been followed up for from 1 month to 7 years postoperatively were recorded. The indication for operation was acute femoral neck fracture in 173 patients and failure following previous hip operation (mostly internal fixation) in 38 patients.

The most recent X-ray films available for each patient were compared with the first postoperative X-ray films for that patient. Acetabular protrusion was measured in millimeters as seen in the antero-posterior view. Variations in the magnification effect between the first and the most recent antero-posterior X-ray films were minimal (10-20 per cent) and did not affect the measurements. No effort was made to separate the collapse of cartilage from other types of prosthetic migration.

Relevant data concerning preoperative status, indication for operation, the operative and clinical results at the time of the latest available radiological examination as well as the follow up time were recorded. A total of 52 different variables were available and were prepared for computer analysis.

Statistical analysis

The variables under study here are given in Table 1. Variables 2-13 are preoperative operative variables and 14-19 are clinical follow up variables.

Information about variables which could be of importance was obtained by pairwise analysis of the variables (mostly dichotomies). The χ^2 test for testing no association based on discrete statistics were used as a screening device. A relationship between the variables was further elucidated by analysing various probability frequency tables by fitting log linear models to the observations (Fienberg 1977, Soreide et al. 1980). The main purpose was to uncover and quantify the effects of each variable directly and indirectly between pairs of variables and between interactions between more than two variables. An interaction is in this paper regarded as being when the effect parameter in the log-linear model is greater than twice that of the standard error or greater weak if it is of lesser magnitude but still greater than the standard error. The test for

Table 1 Variables under study

Variable	Categories	
1 Protrusion	No (0)	Yes (1)
2 Indication for operation	Acute fractures (0)	Old fractures (1)
3 Walking ability before operation	Normal (0)	Limited (1)
4 Previous hip operation	No (0)	Yes (1)
5 Incision used	Anterolateral (0) (Watson Jones)	Posterolateral (1) (Osborne)
6 Fixation	Normal (0)	Others (1)
7 Infection	No (0)	Yes (1)
8 Follow up time	0-12 months (0)	> 12 months (1)
9 Type of hemi prosthesis	Short stem (0)	Long stem (1)
10 Ectopic ossification	No (0)	Yes (1)
11 Quantity of cement	Not optimal (0)	Sufficient (1)
12 Position of femoral stem	Varus (0)	Neutral (1) Valgus (2)
13 Age at the operation	< 75 years (0)	> 75 years (1)
14 Personal opinion	Good (0)	Not satisfactory (1)
15 Ability to walk	Normal (0)	Restricted (1)
16 Pain	No (0)	Yes (1)
17 Range of movement	Good (0)	Restricted (1)
18 Varus migration	No (0)	Yes (1)
19 Distal migration	No (0)	Yes (1)

ions were performed with the ECTA-gram package implemented on the UNIVAC-3 installation at the University of Bergen.

RESULTS

Protrusion and preoperative/postoperative anamniotic variables

Of the 211 patients studied, 56 (26 per cent) were found to have acetabular protrusion ranging from 1-19 mm (mean 5.3 mm). The development of protrusion showed a significant time-dependency ($P < 0.01$) and the frequency table demonstrating the development of protrusion in relationship to the follow-up time is given in Table 2. During the first year a frequency of protrusion of 8.9 per cent was noted. This increased to 28.2 per cent during the second year. After 4 or more years of follow-up, acetabular protrusion was found in 54.3 per cent of the patients, and in nearly half of these patients, the protrusion was greater than 5 mm.

Acetabular protrusion was significantly associated with previous hip operation ($P = 0.04$). Sixteen out of 39 patients (41 per cent) previously operated showed protrusion, whereas only 40 of the 172 patients (23 per cent) without previous hip operation developed protrusion. The other explanatory variables showed no significant association with protrusion ($P > 0.10$).

A log-linear analysis of a three-way table involving the parameters protrusion, follow-up time and previous hip operation assuming

no interaction between follow-up time and previous hip operation and no higher order interaction, gave good fit to the data. The variable age at the time of operation could theoretically be of importance in explaining protrusion. However, a four-way log-linear analysis showed that age can be excluded as an explanatory variable for the development of protrusion.

Protrusion and the clinical results

Protrusion was analysed in relationship to the clinical variables 14-17. The pairwise analyses showed that protrusion had a significant association with pain and the patient's personal opinion ($P < 0.01$) but neither to ability to walk or to range of movement ($P > 0.10$). We also found significant associations between most pairs of the clinical variables.

The possible interactions between protrusion and the clinical variables were further studied by fitting log-linear models to the 5-way table to the observations. The model schematically displayed in Figure 1 gave good fit to the data. It assumes no direct interaction between the variables not connected in the figure and no higher order interactions. Personal opinion shows a positive direct association with both pain and range of movement and also, though somewhat weaker with walking ability. There is no significant direct association between pain and range of movement, and between ability to walk and range of movement but possibly

Table 2 Follow-up time (in months) and degree of protrusion (in mm)
(Row-wise relative frequencies in parenthesis)

Follow-up time	Protrusion			Sum
	0	1-5	6-20	
1-12	93 (91.2)	7 (6.9)	2 (2.0)	102
13-24	33 (71.7)	10 (21.7)	3 (6.5)	46
25-48	13 (46.4)	8 (28.6)	7 (25.0)	28
49-	16 (45.7)	10 (28.6)	9 (25.7)	35
Sum	155 (73.5)	35 (16.6)	21 (10.0)	211

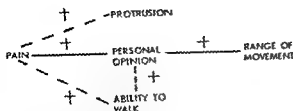


Figure 1 Associations between acetabular protrusion and clinical variables

a weak direct association between pain and ability to walk. The variable personal opinion seems to pick up three different aspects of the clinical status. The ability to walk seems to be the least important factor in determining the patient's personal opinion. Protrusion was not directly linked to personal opinion, or to ability to walk and range of movement. Consequently the association between protrusion and personal opinion revealed in the two-way analysis above is attributable to their common association to pain. Pain appears as the best clinical parameter for protrusion.

Protrusion, loosening of the prosthetic stem and pain

A pairwise analysis showed that the variables related to loosening of the prosthetic stem, varus and distal migration both had significant association ($P < 0.01$) with protrusion and they are strongly related ($P < 0.01$). Varus migration had some association with the patient's personal opinion and with pain ($P < 0.05$) whereas distal migration showed no association with the clinical variables.

A log linear analysis involving the variables distal and varus migration, protrusion and pain showed a positive association between distal migration and protrusion but not between varus migration and protrusion. In addition a second order interaction for the group distal migration, varus migration and protrusion was found. This means that varus migration interacts with protrusion only if it occurs in conjunction with distal migration (as it often does). The migration variables were linked to pain via protrusion. It appears

that in patients who have both protrusion and loosening of the stem, protrusion is the main pain inducing factor.

DISCUSSION

Despite numerous papers presenting clinical results and radiological follow-up following endoprosthetic surgery, the amount of information available on acetabular protrusion is limited.

The usual manner of studying clinical problems has been a pairwise analysis of the variables. Although this often leads to important insights, the results must be judged with care. One can easily miss important marginal relationships between pairs of variables when other variables are present and may interact. A two-dimensional table does not provide the needed insight into these possible interactions. We have found the fitting of multidimensional log-linear models to our data very helpful in order to disclose such interactions among the variables.

In the present study protrusion was found to be clearly time-related. This is in agreement with a previous study in the hospital (Søreide et al. 1979) as well as the findings of Whittaker et al. (1979).

The reported incidence of acetabular protrusion following surgery varies from 37 per cent (Lindholm et al. 1976) to 60 per cent (Danielson 1965). Such figures are of low value as the observation time varies considerably. The time-related incidence presented in Table 2 could be more important. However our data should be judged with care in this respect. It is possible that some selection occurred due to more frequent follow-up examinations of patients with protrusion (note the close association between protrusion and postoperative pain), which may lead to longer follow-up time. With these considerations in mind, we have found an incidence of protrusion of approximately 50 per cent after 4 or more years of follow-up. This is an alarming figure especially

note the association between protrusion

In view of the fairly long survival of treated with primary prosthetic placement for acute femoral neck fractures (Soreide & Lillestøl, in press), the question of whether primary prosthetic replacement is indicated, especially in patients below the age of 80, should be seriously discussed. Stable fixation of a well-reduced subcapital appear to be the preferable alternative. It is clearly of interest to model a relationship where the probability and degree of protrusion is expressed in terms of other covariates found to be significant. Models of the logistic type may be helpful here.

We observed that the follow-up time was not the only factor which influenced the occurrence of protrusion. Protrusion was also clearly correlated with previous operation(s) on the hip. On this basis a total hip replacement may sometimes have to be considered instead of a hemiprostheses.

We could not demonstrate any direct or indirect effect of age of the patient on the development of protrusion. This seems to be in conflict with the findings of D'Arcy & Devas (1976) and Dickreuter (1978) who stated that protrusion was more common in younger patients. Their findings may be explained by the longer life expectancy and greater demands of the young patients.

In several earlier studies pain has been the most prominent symptom associated with acetabular protrusion (Coventry 1964, Peyer 1971, Lindholm et al 1976, Sarento & Gerard 1976). On the other hand, D'Arcy & Devas (1976) and Barr et al (1964) reported that the severity of symptoms did not always correspond with the radiographic changes, while Hinchey & Day (1964), Whittaker et al (1972) and Johnson & Crothers (1975) were concerned about the lack of correlation between the clinical results and protrusion. The present study supports the observation that protrusion is associated with pain. In addition we found interesting links between pain and clinical variables with no direct association with protrusion.

We found that variables related to

loosening of the prosthetic stem were significantly associated with protrusion. This reflects the occurrence of protrusion and loosening of the stem simultaneously, which may simply indicate a time dependency. Our analysis also indicates that in patients with both protrusion and loosening of the prosthetic stem, protrusion is the most pain-inducing factor. This has to be kept in mind when planning a reoperation.

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UNSTABLE TROCHANTERIC FRACTURES

Comparative Analysis of Four Methods of Internal Fixation

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Deep infection was encountered in 2.5 per cent of the cases following surgery in the hip region and in 3.3 per cent of the Ender nailings.

Statistical analyses showed that the quality of the reduction was determined by the comminution of the fracture, and the technical failure of fixation or secondary displacement of the fracture was determined by the quality of the reduction.

Sliding screw-plate fixation was found to be the only suitable fixation method for unstable trochanteric fractures, because of a low failure rate, a low re-operation rate and the possibility of secondary impaction without disturbing the fracture union.

Key words: fractures, internal fixation, femoral neck fractures, internal fixation

Accepted 21 II 80

The internal fixation of unstable trochanteric fractures is primarily a mechanical problem (Damon 1973, Fielding 1973, Frankel 1963, Johnston 1973, Jensen 1980 a, b, Jensen et al 1978, Kaufer et al 1974, Sonstegard et al 1974). The instability of the fractures is due to a lack of bony support over the medial aspect of the femur, because the lesser trochanter and part of the calcar femorale are missing from the mechanical load transmission system. Another cause of instability is posterior detachment from the greater trochanter, resulting in mechanically unreliable reduction with anterior diastasis (Evans 1949, Jensen 1980 d).

The modern trend in the postoperative management of hip fractures in the elderly is

early mobilization with full weight-bearing (Ainsworth 1971, Bosacco et al 1973, Jensen et al 1978, Parker & Reitmann 1976, Rennie & Mitchell 1976, Sahlstrand 1974, Sarmiento & Williams 1970). This makes great demands on both the implant and the osteoporotic bone.

The purpose of the present study was to compare the results of the internal fixation of trochanteric fractures treated with Jewett or McLaughlin nail plates, the sliding screw-plate or by condylocephalic nailing according to Ender. In the present paper only unstable trochanteric fractures (Evans 1949, Jensen 1980 d) will be considered. The results obtained with stable fractures are reported in a separate paper (Jensen et al 1980).

PATIENTS AND METHODS

During the period April 1st 1971 to June 30th 1979 a total of 1 646 patients with trochanteric fractures were admitted to the four departments of orthopaedic surgery participating in the study. There were 1 225 cases of unstable fractures according to the Evans classification system (Evans 1949 Jensen 1980d) 503 were 3 fragmentary without postero-lateral support 188 were 3 fragmentary without medial support and 564 were 4-fragmentary fractures.

Nineteen patients were treated by other methods, 140 died before fracture union and 25 were lost to follow up. This study thus includes 1 071 patients treated by one of the four methods and followed radiologically until fracture union or technical failure were encountered.

The fracture reduction was evaluated from the postoperative X-rays. Anatomical reduction was defined as a diastasis of 4 mm or less over the fracture line. Fracture diastasis of 5 mm or more was looked for medially or laterally in the AP projection and anteriorly or posteriorly in the lateral projection. The nail plate angles were measured as well as the distance from the nail tip to the bone confinements. The fractures were X-rayed regularly until fracture union with registration of the occurrence of technical failures, telescoping of the sliding screw plate or distal slipping of the Ender nails with or without secondary dislocation of the fracture. Technical failures were defined as any complicating fracture bending or breakage of the implant or dislocation of the implant in relation to the bone. All X-rays were evaluated by the three authors. Furthermore the rates of deep infection or osteitis non union and re-operations were recorded. Prophylactic antibiotics were not applied.

In the statistical evaluation of the results multivariate logistic analysis as well as multiple con-

tingency table analysis with successive testing as described by Madsen (1976) were applied.

The median age of the patients at the follow-up examination was 79 years (range 24-107) and the mean age 76 ± 11 years (s.d.). Females constituted 78 per cent (837/1 071) of the patients.

RESULTS

A multiple contingency table analysis revealed that the number of unstable trochanteric fractures increased with age ($P < 0.001$) especially in females.

The distribution of the four methods of treatment in relation to the three types of fracture is shown in Table 1.

Deep infection or osteitis was encountered in 3.4 per cent (10/293) following McLaughlin nail plate fixation in 2.3 per cent (7/309) after Jewett and 2.0 per cent (2/101) after sliding screw-plate fixation. The total infection rate following surgery in the hip region was thus 2.5 per cent (24/97) whereas the infection rate was 3.3 per cent (4/123) following Ender nailing and localised to the knee region. These differences were not significant ($P = 0.8$ Chi square test).

The quality of the fracture reduction in relation to the method of fixation and the nail plate angles applied is listed in Table 2. A multiple contingency table analysis revealed that the quality of reduction was primarily determined by the comminution of the fracture ($P < 0.00005$). This means that the 4-fragmentary fractures were more frequently reduced with diastasis than the 3-fragmentary. The quality of reduction was

Table 1 Treatment of unstable trochanteric fractures

Fracture type	McLaughlin nail plate	Jewett nail plate	Sliding screw plate	Ender nailing	Total
3 fragmentary with postero-lat support	128	116	152	43	439
3 fragmentary with medial support	56	36	42	12	146
4-fragmentary	109	157	152	69	487
Total	293	309	346	123	1071

Table 2 *Quality of reduction and applied nail plate angles*

Reduction	McLaughlin nail plate	Jewett nail plate	Sliding screw plate	Ender nailing	Total
Anatomical in both planes	69 (24%)	102 (33%)	99 (29%)	29 (24%)	299 (28%)
Distasis in lateral plane	46 (16%)	53 (17%)	75 (22%)	25 (20%)	199 (19%)
Distasis in AP plane	57 (19%)	62 (20%)	40 (11%)	21 (17%)	180 (17%)
Distasis in both planes	121 (41%)	92 (30%)	132 (38%)	48 (39%)	393 (37%)
Nail-plate angles					
<139°	95	43	264		
≥140°	198	266			

also correlated with the method of treatment ($P < 0.004$). Fractures treated according to McLaughlin or Ender were reduced with distasis more frequently than those treated by the other methods.

The results of the treatment of unstable trochanteric fractures are listed in Table 3. Union in the postoperative position was obtained in 43 per cent of cases (458/1 071), in 60 per cent (208/346) of sliding screw-plate fixations secondary displacement through telescoping of the screw was experienced and union was obtained in the

resulting position with bony contact. Secondary displacement following Ender nailing was observed in 42 per cent (52/123) of cases with distal slipping of the nails. In an additional 11 per cent (13/123) the distal slipping of the nails occurred without fracture displacement. In most instances the distal slipping caused knee pain.

Non union was observed in 0.7 per cent (2/293) of the McLaughlin cases and in 2 per cent (6/309) of the Jewett cases, but in none of the fractures treated with sliding screw-plate fixation or Ender nailing.

Table 3 *Results of treatment of unstable fractures*

Result	McLaughlin nail plate	Jewett nail-plate	Sliding screw plate	Ender nailing	Total
Union in post operative position	137 (47%)	156 (50%)	117 (34%)	48 (39%)	458 (43%)
Secondary displacement with union			208 (60%)	52 (42%)	260 (24%)
Non-union	2 (0.7%)	6 (2%)	—	—	8 (0.7%)
Technical failure	154 (53%)	147 (48%)	21 (6%)	23 (19%)	345 (32%)
Total	293	309	346	123	1 071

Technical failures were encountered in 53 per cent (154/293) following McLaughlin fixation. A total of 175 technical failures were observed, as listed in Table 4. In 30 per cent (88/293) isolated failure of the nail-plate junction was seen (Figure 1). Implant failures occurred in a total of 38 per cent (110/293) of the cases. The remaining failures were due to osteoporosis allowing the nail tip to move within the femoral head or neck confinements or to penetrate them (Figure 2). A combination of implant failure and failure due to osteoporosis thus occurred in 21 cases. The technical failures caused a varus dislocation of 10° or less in 22 per cent (63/293) and of 20° or more in 25 per cent (74/293) of the cases. The remaining fractures impacted without varus dislocation. Re-operations were performed in 17 per cent (50/293) of the cases following McLaughlin fixation. In 9 per cent (26/293) the re-operations were caused by implant failure. The remaining re-operations were due to infection or to penetration or severe varus dislocation.

Jewett nail-plate fixation was followed by technical failure in 48 per cent (147/309) of the patients, representing 161 failures, as listed in Table 4. Implant failure was observed in 5 per cent (16/309) of the cases (Figure 3). The majority of failures were due to osteoporosis of the femoral head or neck (Figure 4). Varus dislocation of 10° or less was observed in 8 per cent (26/309) and of 20° or more in 12 per cent (36/309) of the cases. Re-operations were performed in 12 per cent (37/309) of the cases. Only 3 per cent (7/309) were due to implant failure, whereas the remainder were caused by infection, penetration or severe varus dislocation.

Sliding screw-plate fixation was followed by technical failure in 6 per cent (21/344) of the cases, as listed in Table 4. Implant failure was experienced in only one case, the remaining cases being due to osteoporosis. Secondary impaction with telescoping of the nail was encountered in 60 per cent (205/344) of the cases (Figure 5). Varus dislocation of 10° or less occurred in 2 per cent (6/344) and

Table 4 Technical failures following internal fixation of unstable fractures

	McLaughlin nail plate	Jewett nail plate	Sliding screw plate	Ender nailing	Total
Migration/cutting < 10 mm	25	63	1	4	93
Migration/cutting > 11 mm	4	5	2	1	12
Penetration of fem head	9	31	2	13	55
Penetration of acetabulum	15	33	3	1	52
Cutting through fem head	12	13	12	1	38
Failure of nail plate junct	100				100
Nail bent or broken	7	12	—	—	19
Plate loose	1	2	1	—	4
Plate bent or broken	2	2	—	—	4
Number of patients	154	147	21	20	342
Varus dislocation < 10°	63	26	6	3	98
Varus dislocation > 20°	74 (25%)	36 (12%)	13 (4%)	6 (5%)	129 (38%)
Re-operations	50 (17%)	37 (12%)	11 (3%)	51 (41%)	149 (44%)



Figure 1 A A 3 fragmentary fracture without postero-lateral support reduced with diastasis medially and anteriorly

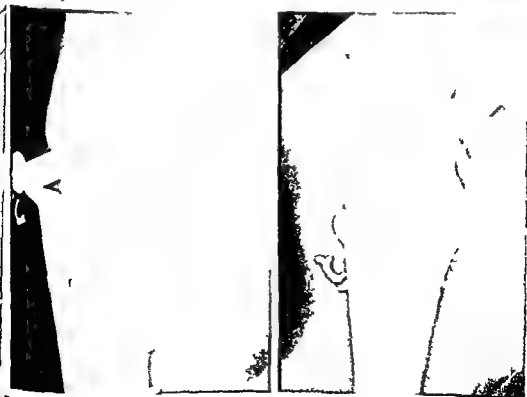


Figure 1 B Failure of the nail plate junction with fat gap fracture of the washer following fixation



Figure 2 A. A 4-fragmentary fracture reduced with diastasis medially and anteriorly



Figure 2 B. Secondary impaction of the fracture followed by penetration of the femoral head



Figure 3 A 3-fragmentary fracture reduced with medial and anterior diastasis. Weight bearing led to bending of the Jewett nail and varus dislocation of the fracture



Figure 4 Unstable reduction of a 3 fragmentary fracture without postero-lateral support. Weight bearing was followed by penetration and varus dislocation

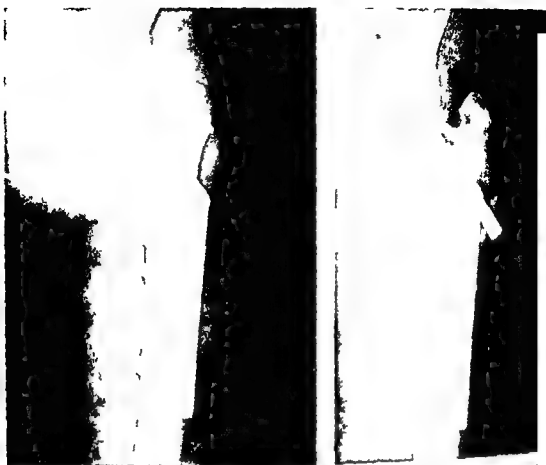


Figure 5 A 4 fragmentary fracture reduced with medial diastasis. Weight-bearing was followed. Impaction of the fracture facilitated by telescoping of the implant until bony support was obtained.

of 20° or more in 4 per cent (13/346). Re-operations were performed in 3 per cent (11/346) of the cases due to penetration and

three cases supracondylar or femoral shaft fractures were sustained during the nailing procedure. All the remaining failures were due to movement of the nail tips in the os-

cases, in 42 per cent (52/123) in connection with secondary fracture impaction, as demonstrated in Figure 7. The re-operation rate was 41 per cent (51/123) because of technical failure, infection or knee problems in connection with distal slipping of the nails.

Secondary fracture dislocation and technical failures were observed within the

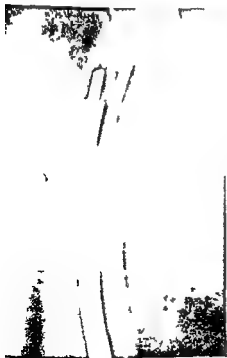
first 4 weeks following the operation in 71 per cent (481/605) of the cases. An additional 11 per cent (114/605) were encountered before the 12th week and only 2 per cent after that time.

Technical failures or secondary displacement followed bi plane anatomical reduction in 17 per cent (51/299) of the cases. The rate increased to 82 per cent (322/393) of fractures with diastasis in both planes. Diastasis in the AP projection was responsible for the displacement in 62 per cent (112/182) of the cases, compared with 59 per cent (11/19) following diastasis in the lateral projection.

A multivariate logistic analysis revealed that fracture diastasis following the reduction was the main cause of secondary displacement or technical failures ($P < 0.0001$). Fracture type as such determined the quality of reduction ($P < 0.00005$). A contingency table analysis revealed that



Figure 6 A Unstable reduction of a 4 fragmentary fracture with medial and anterior diastasis



cant correlations ($P < 0.0005$ to 0.035) between the method of treatment and the positioning of the implant as regards the angle and the position of the nail tips in relation to the femoral head confinements. Further multivariate logistic analyses showed that the method of treatment ($P < 0.0005$) and the position of the nail tip influenced the rate of technical failures and secondary displacement ($P < 0.001$). This means that a mechanically reliable reduction of the fracture is the primary safe-guard against technical failures, and that even the distance from the nail tip to the bone confinements is important and should be between 11 and 15 mm. If anatomical reduction cannot be achieved the sliding screw plate is the only method to avoid complications

Figure 6 B Weight bearing followed by penetration of the nails and varus dislocation of the fracture until bony support is obtained



Figure 7A Unstable reduction of a 4-fragmentary fracture with medial and anterior displacement.

DISCUSSION

Internal fixation of hip fractures with nail-plate implants has been claimed to be followed by fairly high infection rates (Tengve & Kjellander 1978), but the infection rate of 2.5 per cent in the present series confirms the figures given in several other previous observations (Jensen & Michaelsen 1975, Laskin et al 1979, Mulholland & Gunn 1972, Sarmiento 1963), whereas 3.3 per cent of the Ender nailings were followed by infection.

The main aim of internal fixation is to achieve a mechanically reliable fracture reduction (Clawson 1957, Kennedy et al 1957) and consequently a classification system taking these difficulties

into account must be applied for comparison of the results obtained by different methods (Jensen 1980 d). In the present study the fractures were classified according to the degree of displacement from the lesser or greater trochanter (Evans 1949, Jensen 1980 d). A highly significant correlation was found between the fracture type and the probability of achieving sufficient fracture reduction (Jensen 1980 d), thus only 23 per cent of unstable fractures were anatomically reduced in both planes.

As every X-ray was described by the authors according to the same classification system a comparison of the results of different types of treatment is possible. Mistakes in the comparison caused by retrospective, uncontrolled design are of minor importance, as this is a retrospective study and thus unbiased by the author.



Figure 7B Weight bearing was followed by varus dislocation and distal slipping of the nails, causing the complaints. A supracondylar bone fragment had even broken off during the nailing procedure.

Technical failures following McLaughlin fixation of unstable fractures have been reported in 20-46 per cent (Bremner & Raham 1958, Clawson 1957, Foster 1958, Nedenberg et al 1972, Jensen & Michaelsen 1975, Laros & Moore 1974, McLaughlin & Arcia 1955). In the present series a total of 1 per cent technical failures were countered. About one-third of the failures are due to displacement of the nail tip in relation to the osteoporotic bone and in about one-half of these cases the nail protruded through the bone. Two-thirds of the failures are, however, implant failures, the vast majority caused by varus dislocation at the nail-plate junction. Biomechanical studies (Jensen 1980 a,b) showed that loosening of the nail-plate junction in McLaughlin

implants occurs at loads of less than 30 kg. At normal level walking the hip joint load is about three to five times the body weight (Paul 1976, Rydell 1966), thus greatly exceeding the holding power of the nail-plate junction. As the implant is obliged to transmit the hip joint load to the femoral shaft in inadequately reduced trochanteric fractures, the McLaughlin nail-plate is unsuitable for the internal fixation of unstable trochanteric fractures.

The failure rate of Jewett nail plate fixation of unstable fractures has been reported to range from 14-51 per cent (Boyd & Griffin 1949, Dimon & Hughston 1967, Evans 1951, Fielding 1973, Jacobs et al 1976, Johnson et al 1968, Kyle et al 1979, Laros & Moore 1974, Morrison et al 1978, Parker 1955,

Robey 1956) In the present series technical failures were observed in 48 per cent of cases. Less than 10 per cent were due to implant failures. The failure load of Jewett nail plates has been reported to be about 100 kg (Jensen 1980 a). The vast majority of failures with these implants are due to displacement of the nail tip, which often protrudes through the osteoporotic bone. As secondary fracture impaction takes place until bony contact over the fracture line is achieved, the implant must either give way or protrude through the bone. Alterations in the operative technique using a shorter Jewett nail might solve the problems of penetration, but lead to a greater number of cuttings with varus dislocation (Boyd & Griffin 1949, Evans 1951). Consequently the Jewett nail plate cannot be recommended for the internal fixation of unstable trochanteric fractures.

The sliding screw-plate was originally designed with the aim of allowing secondary fracture impaction (Clawson 1964). The telescoping is often painful and followed by leg shortening of 1-2 cm (Clawson 1964, Ecker et al 1975, Harrington & Johnston 1973, Jensen et al 1978, Laskin et al 1979). In the present series secondary impaction was experienced in about 60 per cent of cases but technical failures occurred in only 6 per cent. This low failure rate is consistent with other publications (Clawson 1964, Doherty & Lyden 1979, Ecker et al 1975, Harrington & Johnston 1973, Jacobs et al 1976, Jensen et al 1978, Mulholland & Gunn 1972). Implant failures are extremely rare, which can be explained by a high failure load which exceeds the hip joint load at walking (Paul 1976, Rydell 1966) at least after telescoping (Jensen 1980 c). The failures experienced are displacements and protrusion of the screw tip through the osteoporotic bone. Friedenberg et al (1972) reported this to occur in 19 per cent of cases, but as in the present series re-operations were necessary in only 3 per cent. Jacobs et al (1976) found the sliding screw-plate fixation to be significantly better than the Jewett nail-plate. The present series confirmed this and also found the former method to be better than McLaughlin nail-plate fixation and Ender nailing.

In 1970 an internal fixation system with intramedullary rods for trochanteric fractures

was introduced (Ender 1970, Ender & Sorensen Weidner 1970, Simon Weidner 1971). The system has gained wide popularity. Its reports on the use of the system have also included about 70-80 per cent stable fractures or have not used comparable classification systems. Wynn Jones et al (1977) published a series and compared results with those after McLaughlin nail-plate fixation. There were the same number of technical failures, but a higher rate of re-operations occurred in Ender nailing as a consequence of distal slipping of the nail. In the present series technical failures were observed in 19 per cent of cases, which is



requently re-operations. In former series re-operations have been performed in 8-13 per cent of cases (Pögenfürst & Schräbl 1977, Wynn Jones et al 1977), but technical failure or distal slipping led to re-operations in 4 per cent of the cases in the present series. A more detailed description of the results of most of the Ender cases included in the present series will be published (Jensen & Sonne-Holm 1980). With the problems involved in reducing unstable trochanteric fractures the failure rate and re-operations rate is all too high with the Ender nailing. The system is thus considered unsuitable for the internal fixation of unstable trochanteric fractures.

The present analysis clearly demonstrates that the sliding screw plate is comparable with the McLaughlin Jewett or Ender fixation methods as the only suitable implant for the internal fixation of unstable trochanteric fractures.

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Operations have been performed in 8-13 per cent of cases (Poigenfürst & Schnabl 1977, Wynn Jones et al 1977), but technical failure or distal slipping led to re-operations in 4 per cent of the cases in the present series. A more detailed description of the results of most of the Ender cases included in the present series will be published (Jensen & Sonne-Holm 1980). With the problem involved in reducing unstable trochanteric fractures the failure rate and re-operation rate is all too high with the Ender nailing. The system is thus considered unsuitable for the internal fixation of unstable trochanteric fractures.

The present analysis clearly demonstrates that the sliding screw plate is, compared with the McLaughlin, Jewett or Ender fixation methods, the only suitable implant for the internal fixation of unstable trochanteric fractures.

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TECHNICAL ACCURACY IN HIGH TIBIAL OSTEOTOMY FOR GONARTHROSIS

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A preoperative roentgenological analysis of the whole leg in the standing position is presented as an aid in high tibial osteotomy for medial oostoarthritis of the knee. This analysis provides information about the mechanical condition of the knee, the extent of the deformity and the exact

Key words: gonarthrosis, oostoarthritis, tibial osteotomy

Accepted 24 III 80

High tibial osteotomy is universally accepted as the treatment of choice for early stages of medial gonarthrosis. The effect of the operation is correlated with the correction obtained (Bauer et al 1969, Coventry 1965, 1973, Hagstedt 1974, Seal & Chan 1975).

The closing wedge osteotomy above the tibial tubercle is a safe operation (Jackson & Vaughn 1974) but it needs improvement as regards accuracy. In an earlier series from this hospital (Hagstedt 1974) in 59 out of 166 knees the planned correction was not achieved.

This paper describes our efforts to increase the precision in high tibial osteotomy by improving the preoperative roentgenological examination and modifying the operation method.

MATERIAL

In the Orthopaedic Department of the University Hospital of Lund 59 high tibial osteotomies were

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performed during the years 1975-1977. Seven osteotomies were performed at the Orthopaedic Department of the Hospital in Eksjö during the years 1976-1977. The same indications and pre- and postoperative routines were used for these 66 knees in 60 patients, 29 men and 31 women.

The indication for operation was medial gonarthrosis stages I-III (Table 1, Ahlback 1968, Hagstedt 1974, Norman 1974). The condition was primary in 58 knees and secondary to osteonecrosis in three knees and to trauma in three knees. One young woman (two knees) had *genu varum* without pain. The ages of the patients ranged from 22 to 81 years with a mean of 56 years (Table 1).

METHODS

ROENTGENOLOGICAL METHOD

Theoretical background. On a long roentgenogram (Figure 1), the line between the centre of the femoral head and the centre of the talus represents the mechanical axis of the lower extremity. Normally this axis goes through the middle of the knee at the tibial spine. Any deviation from the

Table 1 Major radiographic stages of the medial type of gonarthrosis

Stage I	Joint space narrowing
Stage II	Joint space obliteration
Stage III	Minor bone attrition
Stage IV	Moderate bone attrition
Stage V	Major bone attrition

Subluxation (translation) of the tibia with secondary arthrosis of the lateral compartment is

mechanical axis represents the degree of varus or valgus malalignment of the knee (Fick 1916, Maquet et al. 1967, Mikulicz 1878).

Theoretical biostatic models of the knee have been developed by Maquet et al (1966, 1967).

They, Ramadier (1967), and Harris & Keen (1970) have used this model in practical work during high tibial osteotomies. However, previous descriptions of the roentgenological technique have not been sufficiently accurate to permit exact re-examination. In order to standardize roentgenological examination, every angle should be defined with reference to the lateral view of the knee for reference and defined the frontal plane as perpendicular to the lateral view.

Roentgenological technique The patient is examined standing on one leg. The lateral view of the knee is monitored by fluoroscopy or by ordinary roentgenogram. The frontal view is taken perpendicular to this lateral view on a 40 cm cassette (100 cm) from a distance of 200 cm with the central ray passing through the knee (Fig 1a, b).

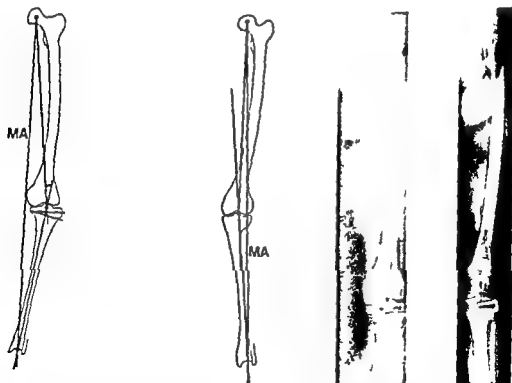


Figure 1a Schematic drawing of the lower extremity showing the mechanical axis (MA), the angle of deformity and the change in the mechanical axis after tibial osteotomy. **b** The roentgenological appearance of the situation described in **a**. A slight overcorrection is obtained after the osteotomy.

To correct the deformity with a high tibial closing wedge osteotomy the wedge to be excised should have the same angle in the same plane as the deviation angle (Figure 1a). Wedges with the desired angle are drawn on the roentgenogram at different levels parallel to the joint surface. The angle of the wedge can then be measured on the lateral cortex, and the distance used by the

geometrical calculation. The vertical height is equal to the wedge angle in radians multiplied by the true width of the tibia,

$$1^\circ = \frac{2\pi}{360} \text{ radians}$$

Postoperatively the correction was calculated from roentgenograms as the change in the angle

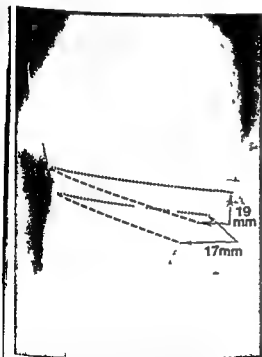


Figure 2 Medial gonarthrosis with a varus malposition of 12° . To correct the deformity with tibial osteotomy a wedge with the same angle should be excised. Two cm below the joint surface the distance on the lateral cortex is 19 mm and at 3 cm below 17 mm. Note that the proximal cut is parallel to the joint line.

between the plane of the tibial condyle and the longitudinal axis of the proximal half of the tibial shaft.

OPERATION

A closing wedge osteotomy was performed above the tibial tubercle according to Coventry (1965). The fibular head was partially resected parallel to the lateral tibial cortex, saving the lateral attachment of the collateral ligament. The dorsal aspect of the tibia was exposed with subperiosteal dissection to the medial margin of the tibia. The level of the osteotomy was decided and the height of the wedge on the lateral cortex was obtained from the roentgenological calculation. The osteotomy was made with an oscillating saw from behind and forwards. The osteotomy gap was closed with an intact periosteal lambeau medially and fixed laterally with a Coventry staple.

It should be noted that 1–2 mm of bone are lost as saw-dust and that it is important to place the wedge angle exactly at the medial cortex. When the osteotomy is done more distally, still above the tibial tubercle, every millimetre of bone lost laterally corresponds to a greater angle compared with that obtained with a more proximal osteotomy (Figure 2). Roentgenographic fluoroscopy was used during the operation to monitor these variables.

Postoperatively the patients were in plaster for 6 weeks and immediate weight-bearing was allowed. Roentgenological examination was made 1 day after the operation, at 1 week, at 6 weeks after the plaster was removed and then at 1 year.

RESULTS

Our aim at the operation of the first 55 cases was to correct the angular deformity in the knee so as to make the weight-bearing line identical with the ideal mechanical axis, i.e. the line through the centre of the femoral head, the tibial spine and the midpoint of the talo-crural joint. For the last 11 osteotomies we have tried to achieve a valgus overcorrection of 4° .

Immediately after the operation four-fifths of the knees were corrected to within $\pm 3^\circ$ (Figure 3). At the 1 year follow-up the correction had been lost in several cases, however two-thirds of the knees remained within $\pm 3^\circ$ of the planned correction. Thirty-two knees

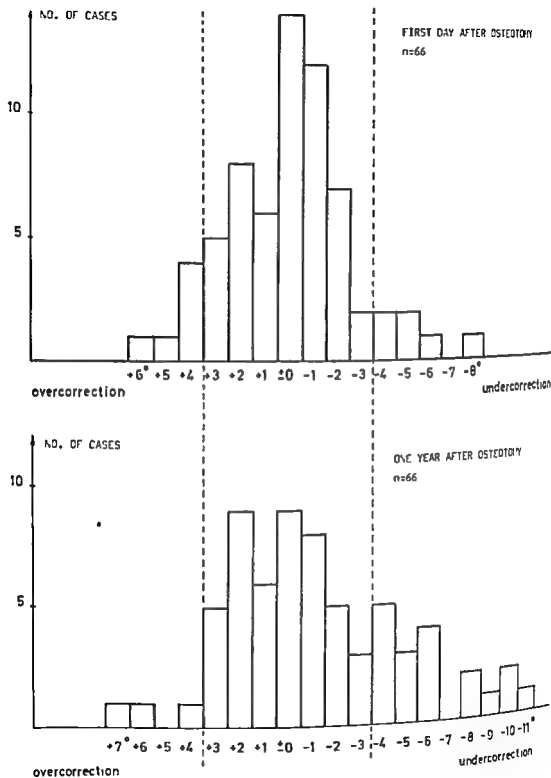


Figure 3 Deviation from the predicted correction (above) First day after operation (below) Situation 1 year after operation

showed a decrease in their correction, 17 knees an increase and 17 knees maintained their initial correction (Figure 4). The loss of correction was less than or equal to 4° in 21 out of 32 knees. Only one knee had an increased correction of more than 4° .

DISCUSSION

In high tibial osteotomy a variety of principles have been applied in order to calculate the deformity that should be corrected. Some authors have suggested that the

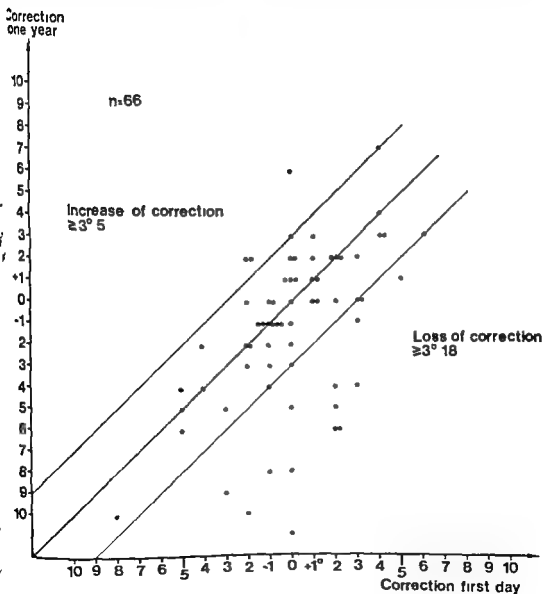


Figure 4 Increase or loss of correction in 66 osteotomies. The Zero line and the lines for $\pm 3^{\circ}$ are drawn.

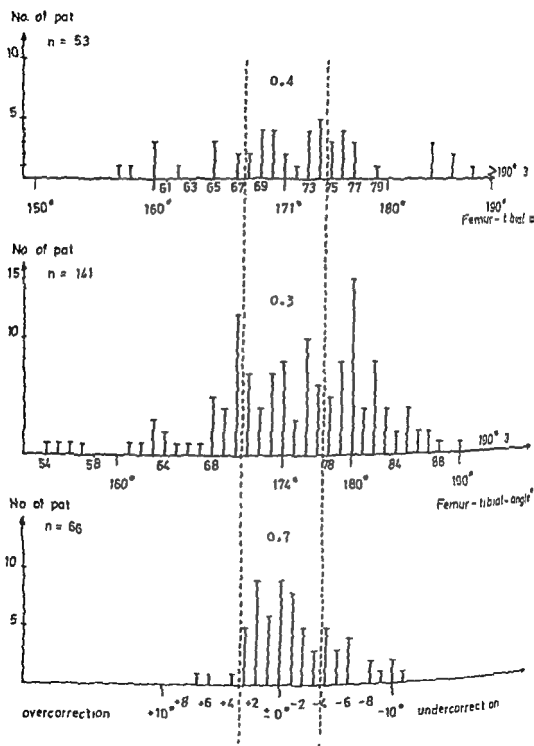


Figure 5 Comparison of the correction in the follow-up materials from (top) Bauer et al. (1969) (middle) Hagstedt (1974), and (bottom) present material

angle between the axes of the shafts of the femur and the tibia should be within the interval $164-178^\circ$ with 174° as the ideal angle. Both weight bearing and non-weight-bearing pictures have been used (Bauer et al 1969, Coventry 1973, Hagstedt 1974, Kettelkamp et al 1976, Shoji & Insall 1973, Slocum et al 1974). Others have tried to determine the mechanical axes of the knee (Harris & Kostuik 1970, Maquet et al 1966, 1967, Ramadier 1967) and at the operation corrected the deformity in such a way that the mechanical axis should then pass through the centre of the knee.

In an earlier series of 166 osteotomies we aimed at a femoro-tibial angle of 174° at weight bearing (Hagstedt 1974), the wedge height was calculated using 1° equal to 1 mm (Bouillet & van Gaver 1961) which is true when the width of the tibia is about 6 cm. The method was abandoned because of the low level of accuracy of the correction at the follow-up. Instead the calculation was made on the roentgenogram of the whole leg where the weight bearing conditions were visualized. The film was taken with the patient standing on one leg with the frontal plane exactly defined. In this way we avoid the errors in measurement caused by too small films, by curvature of the femur and tibia in the frontal plane, and by partial weight-bearing.

The procedure is as close as we can get to the theoretical biostatic model of the knee under weight bearing conditions. Earlier reports of similar methods have not described any standard methods for the measurements and the frontal plane has not been defined.

Edholm et al (1977) have reported a roentgenological method with the orthoradiographic technique adding also another parameter, joint laxity. The non weight-bearing leg is examined under standardized conditions but the assumption that the mechanical axis should coincide with the arithmetic medium of the laxity in an osteoarthritic knee has not been proven.

The method described here gives precise

preoperative information to the surgeon. The postoperative results show that it is also useful in practice (Figure 5). At 1 year following surgery in our series two-thirds of the cases were within $\pm 3^\circ$ of the planned correction as compared to about one-third of the cases of Bauer et al (1969) and Hagstedt (1974). Bauer et al used an interval of around 171° and out of 53 cases of medial arthrosis 23 were found to be within $\pm 3^\circ$. Hagstedt described 141 cases of medial arthrosis and in 45 cases the correction was within $\pm 3^\circ$.

The surgically obtained correction had the same level of accuracy as that obtained when operating with a saw jig (Myrner 1978).

In our series the postoperatively obtained correction had changed by the time it was measured at the follow-up after 1 year. Initially 54 out of 66 knees were found to be within $\pm 3^\circ$ of the planned correction, 1 year later when the osteotomy was healed there were 45 cases with $\pm 3^\circ$. Half of the osteotomies lost correction and in one-fourth the loss exceeded 3° (Figure 3).

Postoperative loss of correction has been observed previously (Hagstedt 1974, Seal & Chan 1975) but it has not been quantified. It appears that loss of correction is a factor which cannot be completely controlled. This together with biomechanical arguments suggests that an overcorrection should be performed in knees with medial gonarthrosis. Therefore in a continued prospective study we now aim at an overcorrection of 4° .

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ADAMANTINOMA TIBIAE

A Report of a New Case

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This report describes a new case of adamantinoma of the tibia which is a rare primary malignant bone tumour. Just over 100 cases have been reported. The symptoms, treatment and problems of diagnosis are briefly discussed.

Key words: adamantinoma tibiae, primary malignant bone tumour

Accepted 3 iii 80

Adamantinoma of the long bones was first described by Fischer in 1913. The name indicated a histological resemblance to the benign but locally invasive tumour of progerating odontogenic epithelium, known as ameloblastoma, which occurs in the maxilla and mandible. This is the second case of adamantinoma tibiae reported to the Norwegian Cancer Registry in 25 years. There have been very few Scandinavian reports on the subject (Fossa 1973, Hierton et al 1979).

CASE REPORT

A 65-year-old man was first seen in 1975. As a 14-year-old he sustained a fracture of the right tibia which

Radiographs showed a 4 cm long destructive process in the right tibia and the possibility of a malignant disease was discussed. Curettage was performed and the histological diagnosis was metastases from a malignant tumour. The patient was examined very carefully to find the primary tumour but none was found. Recurrence of the tumour led to a new curettage in 1976. The microscopic examination showed nests of stellate cells arranged in anastomosing angulated masses supported by fibrous stroma (figure 2a, b). The diagnosis was adamantinoma tibiae. En bloc excision was tried, but a relapse occurred in 1977 and amputation of the femur was performed. The patient now has a prosthesis and

at the 2-year follow-up there were no signs of recurrence or metastases.

DISCUSSION

Adamantinoma tibiae may metastasize even after an interval of many years (Morgan & Mackenzie 1956). There is a great deal of controversy regarding the pathogenesis (Spjut et al 1970, Weiss & Dorfman 1977, Hierton et al 1979). The importance of pre-existing trauma is stressed by several authors (Morgan & Mackenzie 1956, Krishnan et al 1974).

This slow-growing tumour may occur at any age and in the reported cases the ages of the patients have varied from 8 to 74 years.

The symptoms may be a painless swelling in the leg, mild aching or more severe pain. Some patients have no symptoms and some tumours have been discovered incidentally (Krishnan et al 1974).

Identification of the tumour is seldom made before the surgical exploration. The most common roentgenographic differential diagnoses include chondrosarcoma and metastatic carcinoma from an unknown primary site, as in this patient.

Amputation is the treatment of choice if the site of the tumour makes it unsuitable for "en bloc" resection (Hierton et al 1979). The patients should be followed up for many years.



Figure 1 The lesion located in the distal third of tibia. The destructive process extends a distance of about 4 cm. Areas of cortical destruction and small cysts are seen. There is a marked periosteal reaction and also cortical sclerosis of the fibula.



Figure 2a Microscopic examination of the tumour shows rows of stellate cells arranged in anastomosing elongated masses supported by fibrous stroma ($\times 30$)



Figure 2b Trabeculae of epithelial cells with differentiation into squamous epithelium ($\times 430$)

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ANKLE AND FOOT FRACTURES IN DIABETICS PROVOKING NEUROPATHIC JOINT CHANGES

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Neuropathic joint changes, Charcot joints, in diabetics developing after ankle or foot fractures have received little attention in the literature. Three cases are presented here, one in a previously undiagnosed diabetic. The pathogenesis and the management are discussed, and the importance of adequate protection of these fractures is emphasized. Even fractures of the metatarsal bones should be immobilized and weight bearing must be postponed until the bone is firmly united.

Key words: ankle fractures, Charcot joint, diabetic arthropathy, metatarsal fractures, neuropathic joint changes

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Diabetic neuroarthropathy is a complication of diabetes mellitus with spontaneous bone and joint destruction, developing in diabetics with unstable metabolism (Forgasc 1977, Johnson 1967).

The disease ranks among the neurogenic arthropathies which include among others tabes dorsalis and syringomyelia. The main feature is the absence or depression of pain sensation which in the presence of weight-bearing may result in the ultimate breakdown, the Charcot joint characterized by severe, degenerative changes in the joint without pain (Ammitzboell & Jarloev 1975).

The incidence of arthropathy in diabetics is 0.1-0.5 per cent (Forgasc 1977, Lippmann et al 1976). The ankle (11 per cent), the tarsus (24 per cent), the tarsometatarsal joints (30 per cent), the metatarsophalangeal joints (30 per cent) and the interphalangeal joints (4 per cent) are the most common sites (Forgasc 1977).

The role of fractures in the production of neuropathic joint changes has largely been neglected in the literature, and in spite of an

increasing number of observations of diabetic arthropathy in recent years only a few reports have described the progression and management of these fractures.

This paper presents three cases of fractures, in diabetics, initiating neuropathic joint changes, and includes a case in a previously undiagnosed diabetic. The pathogenesis and the management are discussed.

CASE REPORTS

Case 1 62-year-old male. Diabetes for 20 years, controlled by insulin. First seen in the casualty ward in February 1979 because of persistent

He was treated with a supporting bandage and



Figure 1 X-ray, taken 2 months after an injury to the right foot showing fracture of the second metatarsal bone with callus formation (A) After a further 3 months' weight bearing total degeneration of all the tarsometatarsal joints is seen (B)

sing to a typical Charcot foot 3 months later (Figure 1). He was completely free of pain. No ulcers were seen. He was provided with a soft leather shoe with a moulded insole. One year after the injury he still had no pain, but because of the deformity and the varying amount of swelling of the foot he had some trouble in acquiring a suitable shoe.

Case 2 61-year-old female. Diabetes mellitus had not been previously diagnosed. In May 1979, after a rotational trauma of the right ankle, a comminuted trimalleolar fracture with subluxation of the talo-crural joint was found. Reposition and osteosynthesis was performed and a crural circular plaster was fitted (Figure 2). Weight-bearing was not allowed. On the day after admission the patient was found to have a raised blood sugar, and sugar and ketoacid in the urine. Ophthalmoscopy showed simple retinopathy. Insulin treatment was started. After 4 weeks X-ray films showed unchanged anatomical position in the fractures, and weight-bearing was allowed. Eight weeks after the injury the plaster was removed. There had been no intercurrent trauma or episodes of pain. Some swelling of the ankle, but no ulcers and no tenderness was found. X-ray films showed the fractures to be totally redislocated. Reposition was again tried, but was found to be impossible, so another plaster cast was fitted and worn for 3 months. Weight-bearing was allowed after 6 weeks. After removal of the

cast the ankle was stable with limited mobility and without pain. X-ray showed a Charcot joint (Figure 2). A special shoe was made and 7 months after the injury the condition was unchanged. She was managing well without crutches.

Case 3 28-year-old male. Diabetes controlled with insulin for 7 years. Signs of neuropathy and proliferative retinopathy had been found in March 1977, after a fall, he developed swelling but only minor pain in the left foot. X-ray films were taken 12 days after the injury and showed a fracture of the lateral malleolus and of the talus (Figure 3). A plaster cast was applied and weight bearing not allowed until 6 weeks later. The fractures were healing but in a poor position and changes characteristic of a Charcot joint were observed (Figure 3). The patient had no pain, but because of great discomfort with swelling and because he could only walk on the lateral side of the foot, being unable to wear even tailor-made shoes, a crural amputation was performed in October 1977. He has since been wearing a prosthesis.

DISCUSSION

The occurrence of typical Charcot type bone and joint changes secondary to diabetes



Figure 2 Radiographs of the right ankle. (A) Osteosynthesis of a comminuted tri-malleolar fracture (B) The fracture redislocated between 4 and 8 weeks after the injury. After 5 months the fracture healed in a poor position with degeneration of the ankle joint



Figure 3 X ray of the left ankle (A) X ray showing a fracture of the talus 12 days after a fall. In the frontal plane a fibula fracture is visible (B) After 6 weeks in plaster severe degeneration of the ankle and tarsal joints can be seen

neuropathy has been demonstrated by various authors (Knutsson 1951, Martin 1952, Petersen 1960) Neuropathies associated with diabetes mellitus have generally been considered a late manifestation of the disease (Forgasc 1977, Lundbaek 1979) Tile (1973) however, reported eight cases of diabetic mononeuropathy presenting as intervertebral disc herniation in previously undiagnosed diabetics. A case of diabetic arthropathy, occurring prior to the onset of the classic condition of diabetes, has not been reported previously In Case 2 in this paper, the arthropathic changes developed only a few weeks after the diagnosis diabetes mellitus had been suggested

It is widely accepted that neuropathic fractures in diabetics are associated with diabetic osteolysis (Rathery 1973, de Leeuw et al 1975, Forgasc 1977), which is explained by microangiopathy leading to loss of bone mass (Levin et al 1976) and mineral content (Ringe et al 1976) Fractures in an already spontaneously destroyed joint have been described by among others Lippmann et al (1976) who reported one case of ankle fracture and two cases of cuboid fractures and de Leeuw et al (1975) who presented a case of spontaneous bilateral bimalleolar fracture

Johnson (1967) in a review of 118 cases of neuropathic fracture and joint injuries included 10 cases of diabetic origin one of these progressing to Charcot joint changes. This case and the three cases described in the present paper indicate that a fracture in a radiologically normal ankle or foot of a diabetic may produce these changes.

Although only 1-2 per cent of all diabetics have subjective symptoms of neuropathy, nearly all have neurological abnormalities such as some grade of depressed vibratory sense reduced motor conduction velocity or depressed sensation (Lundbaek 1979) Thus when a fracture of the foot or ankle occurs leading to mechanical instability of the joints (Lippmann et al 1976) and sensory deprivation also exists the stresses of continued

weight-bearing may result in the ultimate breakdown

Considering this relationship and the progression of the cases described in this paper the importance of adequate protection of neuropathic fractures in general and of fractures in the foot or ankle of diabetics in particular, must be emphasized All diabetics must be told to present for examination after foot/ankle injuries, even those causing only mild pain After fracture the bones must be immobilized and weight bearing postponed until the bone is firmly united This includes simple, undisplaced metatarsal fracture Because diabetics often have impaired pain sensation pain is not a reliable indication of the state of the fracture

Once a Charcot joint has developed the management in most cases consists of providing proper weight support in individually made shoes (Harris & Brand 1966, Lippmann et al 1976) In cases where the joints are totally disintegrated or the fracture are healing in such a poor position that the wearing of shoes will be intolerable surgical intervention may be necessary Successful cases of surgical fusion of the tarsus in the anaesthetic foot have been reported (Harris & Brand 1966), but considering the delayed healing of fractures in Charcot joints in general (Johnson 1967, de Leeuw et al 1979) and in diabetics in particular (Cozen 1972) amputation often has to be performed.

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ANKLE FRACTURES: SUPINATION-EVERSION FRACTURES OF STAGE IV

Primary and Late Results of Operative and Non operative Treatment

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Supination-eversion fractures of stage IV, 60 treated operatively and 29 non-operatively, were seen at follow up after 3-10 years. This disclosed a statistically significant difference between the results of the two methods. Operation which attempted to re-establish the anatomical position was apparently the better method in the presence of more than minimal displacement or a suspicion of deltoid ligament rupture.

Key words: ankle fractures, arthrosis, non-operative/operative treatment, supination-eversion fractures stage IV

Accepted 21 ii 80

From the present study of malleolar fractures the findings in stage II supination-eversion fractures (SE II) have already been presented (Yde & Kristensen 1980). Unlike the stage II fractures, supination-eversion fractures of stage IV (SE IV) (Figure 1) (N. Lauge Hansen 1942) do not constitute a well-defined sub-group of ankle fractures (Cedell 1967, Yde 1980). This applies particularly to injury to the posterior tibial margin and the medial malleolus, whereas lateral injury shows less variation. At the posterior tibial margin there may be a major or minor fracture of the tibial joint surface or merely a ligamentous injury. Medially there may be fracture of the malleolus or rupture of the deltoid ligament. Furthermore, this type of fracture may be complicated by dislocation causing dorso-lateral displacement of the talus.

Treatment in the various clinics ranges from non-operative (Baek Kristensen 1953, Watson-Jones 1955, Bar 1966, Pohlmann 1971) to operative with attempts being made

to re-establish the anatomical position to a greater or lesser extent. In some clinics severely displaced fractures of the posterior tibial margin and displaced fractures of the medial malleolus are considered indications for operative treatment (Muller 1945, Klossner 1962). Other clinics try, as far as possible, to re-establish the anatomical position in bony and ligamentous injuries especially as regards the lateral malleolus (Willenegger 1961, Weber 1966, Cedell 1967).

In the present study the course of treatment and the late results (subjective, objective, and radiological) of operative and non-operative treatment of SE IV injuries were compared and evaluated.

PATIENTS AND METHODS

During the 8 year period 1968-1976 a total of 488 malleolar fractures were treated in the Department of Orthopaedic Surgery, Hjørring Hosp.

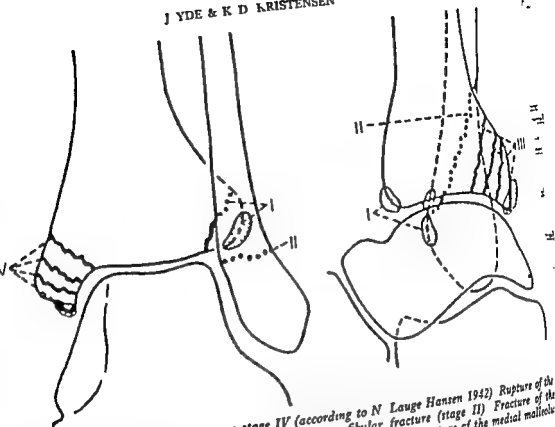


Figure 1 Supination-eversion fracture stage IV (according to N Lauge Hansen 1942) Rupture of the anterior tibiofibular ligament (stage I) Distal oblique fibular fracture (stage II) Fracture of the posterior tibial margin (stage III) Rupture of the deltoid ligament or fracture of the medial malleolus (stage IV)

Table 1 Distribution of fracture types according to the classification of Lauge Hansen (194) Percentage

Fracture types	Hjørring n = 488	Frederikshavn n = 247
Supination-adduction	20.1	18.6
Supination-eversion	33.2	35.2
stage II	2.3	3.3
III	21.5	17.4
IV	0.4	0.4
V-VI	57.4	56.3
Pronation abduction/ pronation-eversion	20.9	21.1
Others	1.6	4.0
	100.0	100.0

Table 2 Criteria and reasons for the exclusion of patients from the study of supination-external rotation injuries stage IV

	Hjørring	Frederikshavn
Total SE IV material	102	43
Not operated on (Hjørring)	23	
Secondary operative treatment (Frederikshavn)		4
Treatment completed elsewhere	4	2
Follow-up not practicable		
dead	6	2
systemic disease	5	1
remote domicile (>50 km)	2	2
refused, others	2	4
Total excluded	42	14
Total seen at follow up	60	29

Denmark, and another 247 in the Department of Surgery, Frederikshavn Hospital, Denmark. The materials do not include patients under 15 years of age, epiphyseal fractures "pure" ligamentous injuries, or fractures caused by direct violence. The Lauge Hansen (1942) classification was used for typing and staging the fractures (Table 1) on the basis of physical and radiological findings and, in the case of the operated group also the operative findings were used in particular as regards injury to the deltoid ligament. In cases where the deltoid ligament was not explored the

examination was made on the basis of clinical examination under fluoroscopy, swelling and tenderness.

Primary osteosynthesis was performed on 79, and these 79 cases form the basis of the follow-up study of the operated SE IV injuries. Operation

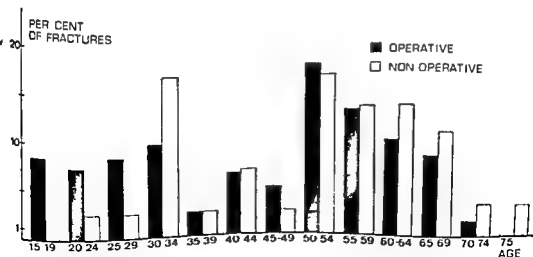


Figure 2 Age distribution.

Table 3 Occupational strain on ankle joint Percentage

Group	Occupation	Operative treatment n = 60	Conservative treatment n = 29
1	unprotected, heavy fisherman, farmer, woodcutter, shipyard worker	28.3	27.2
2	unprotected factory worker, shopkeeper, cleaner (full time)	23.4	14.0
3	possibility of protection cleaner (part-time) country housewife	20.0	7.0
4	little strain on legs housewife, teacher, student	28.3	51.8

was not performed in 23 cases because of minor displacement (13 patients, all over 50 years of age) poor condition of the soft tissues (3 patients all over 50) patient refusal (6 patients) and late arrival (1 patient) 6 days after the trauma. In Frederikshavn 43 fractures were treated 6 of which had talo-crural dislocation. Non-operative treatment was tried first in all cases but in 4 cases osteosynthesis was required a few days later because of pronounced fracture displacement. The remaining 39 fractures constitute the non-operated group.

Sixty patients treated by operation (Hjorring) and 29 treated non-operatively (Frederikshavn) were seen at follow-up in the course of the winter 1978/79. The reasons for the reduction in the size of the materials are given in Table 2. The sex ratio (males/females) was 0.8 for the operated patients and 1.1 for the non-operatively treated ones. Figure 2 illustrates the age distribution. The main aetiological groups (operated/non-operated) were sport 5/2 traffic 6/3 'fall at same level' 43/19 and 'fall to another level' 3/4. The occupational strain on the ankle joint in the two materials is shown in Table 3. The primary fracture displacement according to the classifications of Baek Kristensen (1953) and Cedell (1967) (cf. Table 4) is shown in Table 5. Tables 6 and 7 give the types of injury to the posterior tibial margin and the medial malleolus.

OPERATIVE TREATMENT (HJØRRING)

As a rule the operations were done in a bloodless field. The injuries were exposed through slightly arcuate incisions at the lateral and medial malleolus. In fractures of the lateral malleolus the

aim was accurate reduction and stable fixation (Table 8). Until the middle of 1974 the steel wire cerclage advocated by Cedell & Wiberg (1962) was used (Figure 3), but since that time small screws applied by the technique recommended by the A group have been used in most cases (Figure 4). In a few cases another method was employed. In the event of rupture in the ligament proper the anterior tibio-fibular ligament was sutured.

by the staple designed by ... placed parallel with the ligament (Figure 3). Rupture of the deltoid ligament was sutured. Fractures of the medial malleolus were reduced and fixed by Palmer pins (Figure 3), but in one case by small cancellous screws. Displaced fractures of the posterior tibial margin comprised more than one-quarter of the joint surface were, if possible accurately reduced and fixed by cancellous screws inserted from the anterior aspect (Figure 4). A suction drain was inserted, and after a below knee plaster cast had been applied the leg was positioned in elevation for about 5 days. Thereafter the patients were mobilized but without weight bearing on the affected leg. When the plaster cast was removed 6-8 weeks after the operation the patients were instructed in exercises, and increasing weight bearing was permitted. Within the first 6 months after the operation as a rule 2 weeks after removal of the plaster cast, the osteosynthesis material was totally removed in 29 patients and partially in 25. In 6 patients the implant was left. Thus 48 patients were under general anaesthesia twice. The mean stay in hospital was 15 days, range 5-21 days.

Table 4 Comparison of the classifications of radiological fragment displacement

	Back Kristensen (1953)	Cedell (1967)
<i>lateral malleolus</i>		
Anatomical		No displacement.
Good	No lateral displacement Dorsal displacement ≤ 2 mm	Slight rotation
Medium	Lateral displacement ≤ 2 mm. Dorsal displacement 2–5 mm.	
Poor	Lateral displacement > 2 mm Dorsal displacement > 5 mm	Lateral and/or dorsoproximal displacement. Marked rotation. Valgus position
<i>medial malleolus</i>		
Anatomical		No displacement.
Good	No lateral displacement. No angulation. Dorsal and ventral displacement and fracture diastasis ≤ 2 mm	Slight rotation. Dorsal or ventral displacement ≤ 1 mm.
Medium	Dorsal and ventral displacement and fracture diastasis 2–5 mm. Medial displacement ≤ 2 mm	
Poor	Displacements larger than above Lateral displacement. Angulation	Dorsal or ventral displacement > 1 mm. Lateral or medial displacement. Marked rotation. Valgus position
<i>lateral ligament</i>		
Anatomical		No displacement of the talus.
Good		No displacement of the talus
Poor		Lateral displacement or valgus position of the talus.
<i>anterior tibial</i>		
Anatomical		No displacement.
Good	Fragment $>$ thin shell. Displacement ≤ 2 mm.	Fragment $\leq \frac{1}{4}$ of the articular surface with displacement ≤ 2 mm.
Medium	Displacement 2–5 mm	
Poor	Displacement > 5 mm	Fragment $< \frac{1}{4}$ of the articular surface with displacement > 2 mm. Fragment $> \frac{1}{4}$ of the articular surface with displacement.

Table 5 Radiological degree of displacement before treatment (classifications according to Baek Kristensen 1953 and Cedell 1967) Percentage

	Operative treatment n = 60	Conservative treatment n = 29
Baek Kristensen		
good	3.4	17.3
medium	18.3	37.8
poor	78.3	44.9
Cedell		
anatomical	0.0	0.0
good	1.7	10.3
poor	98.3	89.7

NON-OPERATIVE TREATMENT (FREDERIKSHAVN)

Reduction was performed under general anaesthesia in 15 patients and without general anaesthesia in one. Thirteen patients were fitted with plaster casts without attempts at reduction. All were admitted for an elevation regimen. At the end of 1-3 weeks weight-bearing was started in a below knee walking cast which was removed 7-9 weeks after the trauma and thereafter full weight-bearing was allowed. The mean stay in hospital was 14 days, range 5-21 days.

The patients were examined at the follow up clinically and radiologically by the authors. The mean follow-up period was 5.6 years for the operated fractures and 6.8 years for the non-operatively treated ones, range 3-10 years.

Table 6 Injuries to the posterior tibial margin Percentage

	Operative treatment n = 60	Conservative treatment n = 29
No fracture	25.0	44.8
Shell	8.3	17.2
Affection of the articular surface		
≤ 1/4	28.3	34.5
> 1/4 ≤ 1/2	11.7	0.0
> 1/2	6.7	3.5

Table 7 Injuries to the medial aspect of the ankle joint Percentage

	Operative treatment n = 60	Conservative treatment n = 29
Deltoid ligament	41.6	27.6
Shell < 1/2 cm	5.0	17.2
Transverse fracture	43.4	41.4
Oblique fracture	10.0	13.8

RESULTS

Primary results

The radiological results of reduction were recorded about 2 weeks after treatment was started (Table 9). Within the operated group 70.0 per cent obtained "anatomical" reduction, a result which was not achieved in any patient in the non-operatively treated group. The main cause of a non-anatomical reduction after operation was fracture of the posterior tibial margin. No operated cast remained in the "poor" group according to the Baek Kristensen classification. Following closed reduction the position of the fracture was not improved according to the Cedell classification, whereas 10 had changed from "poor" to "medium" when the classification of Baek Kristensen was applied.

Local complications occurred in two patients after operative treatment. One of these patients developed deep thrombophlebitis and the other skin necrosis after removal of the osteosynthesis material. In the

Table 8 Fixation devices used for the fibula fracture

Cerclage	4
Palmer pin/Kirschner wire	1
Small screws	1
Small plates	1
Combination	6



Figure 3 Fixation of the distal oblique fibular fracture by cerclage and fixation of the medial malleolar fracture by Palmer pins. The anterior tibiofibular ligament is sutured and strengthened by a staple.

latter case healing was obtained in 3-4 months. Non-operative treatment was not associated with any complications.

The period off work was recorded after excluding the patients in the group exposed to least strain on the legs (cf Table 3, group 4). Patients treated by operation were off work for an average of 16.0 weeks, those treated non-operatively for 18.8 weeks.

Late results

The follow-up included a clinical and a radiological examination. Symptoms were classified according to Baek Krstensen (1953) and Cedell (1967), signs according to Baek Krstensen (1953), Cedell (1967) and Weber (1966). Articular changes on the X-ray films were recorded according to the criteria of Magnusson (1944) and Weber (1966). Comparison of subjective and objective results was according to the classifications of Cedell, as they make the strictest demands.

Subjective results (Table 10)

(1) good The patient is completely symptom free or rarely has quite negligible symptoms of

pain, swelling, stiffness or tiredness, but only after extra exertion.

(2) medium Moderate symptoms of pain, swelling, stiffness, or tiredness after exertion, but no reduced capacity for work and in most cases a normal capacity for exercise and sports.

(3) poor Severe symptoms of pain, swelling, stiffness, or tiredness especially on exertion, and as a rule reduced capacity for work.

In the operated group the medium and poor results were due to mild cicatricial pain (1 patient), a tendency to swelling (2), moderately restricted mobility in the ankle joint combined with unprotected, heavy work (1), and arthrosis pain (3). In the remaining 3 patients there was no objective or radiological explanation for the complaints. In the non-operatively treated group the symptoms were due to arthrosis in all 13 cases. The materials are too small for the purpose of demonstrating a definite association between the position obtained by the reduction and the subjective results in the two groups.

Objective results (Table 12) Cedell's classification, with minor modifications, was



Figure 4 Fixation of the distal oblique fibular fracture by small AO screws and fixation of a posterior tibial fragment by cancellous screws.

Table 9 Radiological result of reduction after operative and conservative treatment (classifications according to Baek Kristensen 1953 and Cedell 1967) Percentage

	Operative treatment n = 60	Conservative treatment n = 29
Baek Kristensen		
good	91.7	20.7
medium	8.3	69.0
poor	0.0	10.3
Cedell		
anatomical	70.0	0.0
good	16.7	6.9
poor	13.3	93.1

used (Table 11). The most important findings after operative treatment were: a limp (1 patient), moderately increased circumference of the lower leg (2), reduced calf circumference (1), tenderness of ligaments (3), and reduced range of motion (1). After non-operative treatment a limp (1), moderately increased circumference of the lower leg (2), reduced calf circumference (2), tenderness of ligaments (4), and reduced range of motion

Radiological results (Table 13). The injured ankle joint was X-rayed in three views and compared with the good side. The oblique view was that used by Bolin (1961) which best reproduced the fibular-malleolar rotation and the joint between the fibula-malleolus and talus.

No changes in position had occurred since the primary radiological result of reduction. Two non-operatively treated patients had pseudarthrosis at the medial malleolus. Both had mild arthrosis causing in one of them moderate symptoms and objective findings, while the other patient was symptom-free. Radiological arthrosis was present in 12 of the operated patients and in 19 of those treated non-operatively, but with no complaints and normal objective findings in 8 of the former and in 6 of the latter group.

The therapeutic results after operative and

non-operative treatment were subjected in two-sided statistical tests. This gave the following probabilities: Symptoms $P = 0.009$ (Fisher's exact test), signs $P = 0.013$ (Fisher's exact test), radiological arthrosis $P < 0.001$ (χ^2 test). At significance level of $P < 0.05$ the results of the two methods differ: operative treatment showing better results than non-operative treatment.

DISCUSSION

The age distribution and sex ratio in the two materials are similar. On the other hand, the occupational strain on the ankle joint (cf. Table 3), the primary displacement of the fracture (cf. Table 5), and the frequency of major fractures of the posterior tibial margin (cf. Table 6) were greater in the operatively treated than in the non-operatively treated group. In the non-operatively treated group the staging is based exclusively upon clinical and radiological data. Therefore, a few type SE II and III fractures may have erroneously been included in the non-operative group (Cedell 1967). In other words, the operated fractures are loaded with more strain factors than the non-operated ones, but the severity of these factors and their role in the late results cannot be definitely evaluated.

Baek Kristensen (1953), in a follow up of 83 SE IV fractures which had been treated by closed reduction according to the principles of Lauge Hansen (1942) found the following subjective results: 77.8 per cent "good", 20.0 per cent "medium", and 2.2 per cent "poor".

Table 10 Late subjective results (classification according to Cedell 1967). Percentage

	Operative treatment n = 60	Conservative treatment n = 29
Good	83.3	55.2
Medium	13.3	31.0
Poor	3.4	13.8

Table 11 Classification of late objective results (+) increase, (-) decrease (modification of Cedell's classification)

Components	Good	Medium	Poor
Lower leg (+)	normal ≤ 1 cm	normal > 1-2 cm	limp ~ 2 cm
Foot size (-)	≤ 1 cm	> 1-2 cm	~ 2 cm
Joint tenderness	none	slight	marked
Plantar flexion (-)	< 15°	16-30°	~ 30°
Rotation-supination (-)	< 1/2	< 1/2	~ 1/2
Transverso-planus	none	slight	marked

In the present material the results obtained in the Kristensen's classification) were after operative treatment 88.3 per cent, 8.3 per cent and 3.4 per cent, respectively, after non-operative treatment, in which reduction was attempted in 51 per cent of the cases, the results were 69.0 per cent, 24.1 per cent and 6.9 per cent, respectively. Cedell (1967) in his follow-up of 55 operatively treated SE IV fractures found subjectively 83.6 per cent "good", 9.1 per cent "medium", and 7.3 per cent "poor", respectively. Objectively 43.6 per cent "good", 50.9 per cent "medium", and 5.5 per cent "poor", arthrosis 61.8 per cent, (+) 21.8 per cent, "++" 12.8 per cent, "+++" 1.8 per cent, and "++++" 1.8 per cent. The subjective result is almost identical with that in the present group treated with osteosynthesis, while the objective result of the arthrosis rate differ significantly from present findings.

In addition to the two studies mentioned above, several authors have reported on the results of non-operative (e.g. Bar 1966, Jaschke & Götz 1974, Pohlmann 1971) and non-operative (e.g. Burwell & Charnley 1965, Nonnemann & Brautigam 1977, Nankar 1977, Weber 1966) treatments of

malleolar fractures, but only a few of these studies have been comparative (Gay & Vignard 1963, Kett et al 1965, Klonner 1962, Lecestre & Ramadier 1976, Martiney et al 1970, Willenegger et al 1971). Comparison with the results of the last-mentioned authors is difficult because they have used another, less differentiated classification and a different registration of clinical and radiological findings.

Cedell (1967) comparing the late results of operative treatment with May's results (1944) after non-operative treatment, found that in operative treatment when (i) the anterior tibio-fibular ligament is injured with a chip of avulsed bone, (ii) the lateral malleolar fragment is displaced, (iii) a fragment of the posterior tibial margin is displaced, (iv) one-quarter of the articular surface is displaced, or (v) a medial malleolar fracture is displaced, or (vi) when there is a complete rupture of the deltoid ligament.

The present study shows a significant difference between the results of the two

Table 12 Late objective results (classification according to Cedell 1967) Percentage

	Operative treatment n = 60	Conservative treatment n = 29
Good	86.6	62.0
Medium	11.7	34.5
Poor	1.7	3.5

Table 13 Podiologic arthrosis (classification according to May 1944) Percentage

	Operative treatment n = 60	Conservative treatment n = 29
0	10.0	13.8
(+)	50.0	51.7
++	33.3	51.7
+++	1.7	6.9
++++	4.2	13.8

methods, operative treatment giving better results. It is therefore recommended that operative treatment is used in SE IV fractures with more than minimal displacement, a major displaced fragment of the posterior tibial margin, or with a suspicion of deltoid ligament rupture. In this operation an attempt should be made to re-establish an anatomical position, and this applies both to the ligamentous and bony injuries.

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NON-OPERATIVE TREATMENT OF ACHILLES TENDON RUPTURES

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A study of 10 patients treated non-operatively for Achilles tendon ruptures is reported. Re-ruptures occurred in three patients. The end-results as regards plantar flexion power and ankle mobility were comparable with those obtained in 24 patients treated operatively.

Key words: Achilles tendon rupture, treatment

Accepted 24 iv 80

It has generally been accepted that total rupture of the Achilles tendon should be treated by operation. The first series of patients treated systematically with plaster immobilization alone appeared in 1968 (Lea & Smith 1968).

The purpose of the present study was to compare the results previously obtained with operative procedures with those obtained in a non-operatively treated series.

PATIENTS AND METHODS

In the years 1976-1978, 10 patients with total Achilles tendon ruptures were treated non-operatively according to the method of Lea & Smith (1972) by immobilization in a below knee plaster cast with the foot in equinus position for 8 weeks. For an additional 4 weeks a heel raise of 2.5 cm was applied. Admission to the hospital ward was not required.

The patients were examined at follow-up 2.1 (range 1.2-2.7) years after the injury. The maximal plantar flexion force was measured by a pressure transducer (LX1420A, National Semiconductor Corporation, USA). Three tests were performed for each leg with the hip, knee and ankle points at right angles. The highest score was used and the unaffected leg served as a control. A mathematical correction of the measurements was performed as the right leg is

57 per cent stronger on average than the left (Damholt & Tørmansen 1978).

Pronation, supination, plantar flexion and dorsiflexion were recorded by an electromechanical device measuring the angular movements with an accuracy of ± 1 degree.

RESULTS

Re-ruptures occurred in three cases, all within 5 weeks after cast removal. One happened apparently without a new trauma. In two patients the non-operative treatment was repeated, but led to a second re-rupture in one case. Eventually, two patients were treated operatively.

The results of the clinical follow-up examination are shown in Table 1. Of the ten patients, eight were very satisfied with the end-result, and none was dissatisfied. They had been absent from work for 6.4 (range 0.5-26) weeks. Sports activities were resumed by five out of eight of the patients.

DISCUSSION

The operative treatment of Achilles tendon ruptures has been complicated by skin necrosis, sural nerve affection and

Table 1 Results of the clinical follow-up examination of 10 patients treated non operatively for Achilles tendon ruptures

Reduced power	(per cent)	11 (range 19 to -12)
Reduced dorsiflexion	(degrees)	4 (range 14 to -1)
Reduced plantar flexion	(degrees)	2 (range 12 to -4)
Reduced pronation	(degrees)	2 (range 15 to -10)
Reduced supination	(degrees)	4 (range 14 to -4)
Increased tendon width	(mm)	8 (range 19 to 4)

venous thrombosis. This has been a stimulus to try non-operative procedures. In the 1970s encouraging results of non-operative treatment were published (Gillies & Chalmers 1970, Lea & Smith 1972, Lildholdt & Munch-Jørgensen 1976, Nistor 1976). Others (Inglis et al 1976, Jacobs et al 1978) still found operative treatment to be superior. The frequency of re-ruptures reported is listed in Tables 2 and 3.

In our series the mobility of the ankle and the power of plantar flexion were both in the same range as that obtained in 24 patients previously treated by operation (not published). Re-ruptures, however, were much more frequent in the non-operatively treated series. Non-operative treatment saves hospital beds. However, in the event of a re-rupture the duration of treatment will be considerably prolonged for the patient.

Table 2 Re ruptures in Achilles tendons primarily treated operatively

Author	Year published	No of cases	No of re-ruptures
Solheim	1960	79	1
Kristensen & Andersen	1970	37	1
Lea & Smith	1972	255	4
Inglis et al	1976	48	0
Heim & Heim	1977	99	1
Hegh & Lauritzen	1977	80	0
Dekker & Bender	1977	21	0
Jacobs et al	1978	26	0
Percy & Conochie	1978	77	0
Borgi et al	1978	36	1
Ma & Griffith (percutaneous repair)	1977	12	0
Total		770	8 (1 per cent)

Table 3 Re ruptures in Achilles tendons primarily treated non-operatively

Author	Year published	No of cases	No. of re-ruptures
Lea & Smith	1972	60	7
Lildholdt & Munch Jørgensen	1976	14	1
Nistor	1976	12	0
Inglis et al	1976	31	9
Jacobs et al	1978	32	7
Borgi et al	1978	23	2
Present series		10	3
Total		188	29 (15 per cent)

The disadvantage then of non-operative treatment is the high proportion of re-ruptures, and in this respect it cannot at all compete with operative treatment. The results of non-operative treatment therefore are not good enough for it to be recommended as a routine procedure. Nevertheless, in patients in a high risk category as regards operative treatment or in patients refusing an operation conservative treatment as described by Lea & Smith (1972) should be considered.

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HEALING OF ULCERS ON THE FEET CORRELATED WITH DISTAL BLOOD PRESSURE MEASUREMENTS IN OCCLUSIVE ARTERIAL DISEASE

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The frequency of healing of ulcers on the feet in patients with occlusive arterial disease (measured by the systolic pressure in the heel (SPP)) was correlated with the frequency of healing of ulcers on the feet in patients with ulcerations) had diabetes mellitus. The treatment was conservative. In 42 feet the ulcers healed after an average period of 5.8 months, in 24 feet major amputation became necessary after an average of 4.3 months. The frequency of healing correlated significantly with the three distal blood pressure measurements.

feet as regards the healing rates although infection and peripheral neuropathy were frequent in the diabetic group. The data show that the systolic digital blood pressure is a particularly valuable prognostic parameter.

Key words: amputation, ankle blood pressure, arteriosclerosis, diabetes mellitus, diabetic gangrene, distal blood pressure, ischaemic ulcers, neuropathic ulcers, photo-cell, skin perfusion pressure, strain gauge plethysmography.

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The assessment of the prognosis of ulceration or gangrene of the foot determines the treatment of patients with occlusive arterial disease of the legs. Arterial reconstruction or amputation may be necessary when ischaemia is progressive, on the other hand spontaneous healing is not uncommon (Mathiesen et al. 1970). Pedal pulses are often absent even in mild claudication and cannot be used in the prognosis. Rest pains are alarming but may be transient, and objective signs of local ischaemia are often difficult to evaluate.

Healing of skin lesions on the feet has been shown to correlate with the systolic digital and the systolic ankle blood pressure (Carter 1973) and healing of surgical wounds following major amputations correlates well with the local skin perfusion pressure (Holstein 1973, Lassen & Holstein 1974, Holstein et al. 1979 a and b) and the segmental systolic blood pressure (Barnes et al. 1976, Rames et al. 1976, Wagner & Buggs 1978).

The present study was undertaken to

Table 1 Age distribution in 66 cases of ulcers on the feet

		41-50	51-60	61-70	71-80	81-90	Total	*Age (years)
Cases without diabetes mellitus	Healing	1	2	8	6	0	12	66.4
	Major amputation	0	1	3	7	3	14	72.6
Cases with diabetes mellitus	Healing	0	4	13	8	0	25	63.2
	Major amputation	0	2	1	4	3	10	72.4

*arithmetic mean age

male/female ratio 39/27 = 1.44 Arithmetic mean age without diabetes mellitus (DMI) 69.2 years and DMI = 68.0 years.

compare three different distal blood pressure parameters in relation to healing of ulcers on the feet in occlusive arterial disease the systolic digital blood pressure (SDBP), the systolic ankle blood pressure (SABP) and the skin perfusion pressure on the heel (SPPH)

PATIENTS AND METHODS

Patients In a 1 year period (13 1973 to 28 2 1974) 68 patients with 72 ulcerated feet evaluated in the Department of Clinical Physiology for arterial insufficiency were included in the series. Six patients died leaving 62 patients with 66 ulcerated feet for study. The distribution

in the 32 diabetic patients was 5 years or less in 7 patients and 10 years or more in 20 patients. Eleven patients were taking insulin.

The patients' inclusion in the study was based on the following criteria:

- (1) The presence of an ulcer on the toes or foot distal to the ankle joint and comprising a skin area of at least 5 by 5 mm and penetrating at least to the subcutis.
- (2) The presence of occlusive arterial disease of the legs as determined by the strain gauge technique (see below) on the ankle and on the first toe.
- (3) Duration of the lesion of at least 1 month after the first examination in the department. Thereby lesions were excluded which were so severe that major amputation had to be carried out as soon as the patient's condition allowed surgery as well as those lesions which healed rapidly and uneventfully.

- (4) Treatment of the arterial condition during follow up by vascular reconstructive sympathectomy or treatment in the form of induced hypertension by mineralocorticoid (Lassen et al. 1968) caused the patients to be excluded from the series. However, patients with skin lesions previously treated with vascular reconstruction were included provided that a skin lesion and significant occlusive arterial disease was still present.
- (5) Patients with clinical signs of chronic venous disease - in addition to the arterial occlusion - were excluded from the study.

The treatment was thus conservative consisting of relevant dressing, antibiotics (after culture) in the case of deep infection and surgical drainage and revision in the presence of pus. When necessary, footwear was corrected and external pressure on the lesions was relieved by individually fitted insoles (Holstein et al. 1976).

Methods The following parameters were recorded with intervals of about 1 to 3 months: (1) The systolic digital blood pressure (SDBP), (2) The systolic ankle blood pressure (SABP) and (3) The skin perfusion pressure on the heel (SPPH). The SDBP and the SABP were measured by the strain gauge technique (Strandness & Reif 1965; Gundersen 1972; Nielsen et al. 1972) using a miniature cuff inflatable part 2.4 x 10 cm on the first toe and a 12 x 26 cm cuff at the ankle. The presence of ulcerations on the first toe did not prohibit measurements. However, in two cases where the first toe was necrotic, measurements were performed on the second toe using a 1.6 cm broad cuff. Before inflation of the manometer cuff the toes were carefully emptied of blood by squeezing them gently with the fingers. The SPPH was measured by the photoelectric

Table 2 Neurological findings

	No. of cases	
	With DM*	Without DM
<i>Reflexes</i>		
Ankle reflex absent knee reflex absent	14	0
Ankle reflex absent knee reflex present	17	6
Ankle reflex present, knee reflex present	4	25
<i>Sensation in the toes</i>		
**Vibration sense { absent	16	3
{ decreased	16	15
" on of temperature { absent	12	2
{ decreased	14	4
Perception of pinprick { absent	8	2
{ decreased	16	4
Perception of light touch { absent	3	2
{ decreased	10	1
Position sense absent	2	0
Intact sensation	3	13

* DM - diabetes mellitus.

** Vibration sense examined objectively by biothesiometry. Decreased vibration sense 30-50 Volt Absent on sense > 50 Volt.

The finding of two or more abnormal neurological parameters was considered as peripheral neuropathy

technique (Nielsen et al 1973, Holstein et al 1979 c) using a photoelectric surface probe for recording of the skin blanching threshold external pressure measured with a small plastic cushion connected to a mercury manometer. The presence of arterial insufficiency was indicated by the finding in all the patients of an SABP below systolic auscultatory brachial blood pressure or by

an ankle to toe gradient of 64 mmHg or more (Nielsen et al 1972). Moreover the presence and the severity of peripheral neuropathy was determined by clinical examination with the exception of the vibration sense, which was measured by biothesiometry on the pulp of the first toe (Steiness 1963). Table 2 shows the neurological findings.

Table 3 The healing rates at different distal blood pressures

	First and final measurements		First and final measurements		First and final measurements	
	< 20 mmHg		20-29 mmHg		≥ 30 mmHg	
SDBP						
Non-diabetics	3/12	0/13	1/3	4/5	13/16	13/13
Diabetics	4/12	2/9	3/5	3/6	18/18	20/20
Total	7/24	2/22	4/8	7/11	31/34	33/33
SABP						
Non-diabetics	1/7	0/8	8/16	11/17	8/8	6/6
Diabetics	0/2	1/5	10/18	9/15	15/15	15/15
Total	1/9	1/13	18/34	20/32	23/23	21/21
SPFH						
Non-diabetics	1/5	3/14	7/16	7/10	9/10	7/7
Diabetics	2/5	0/2	7/13	9/17	16/17	16/16
Total	3/10	3/16	14/29	16/27	25/27	23/23

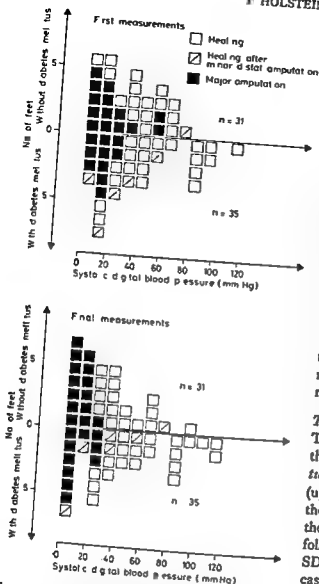


Figure 1 Healing of 66 ulcerated feet in relation to the systolic digital blood pressure (SDBP)

Experimental conditions The patients were examined in the supine position with legs horizontal and at a room temperature of $25^{\circ} \pm 2^{\circ} \text{C}$. The temperature of the toes was at least 25°C before measurements were started and the systemic blood pressure was measured repeatedly by auscultation using a 26 by 12 cm cuff round the left arm.

RESULTS

Mortality Six patients (9 per cent) with six ulcerated feet died before the final outcome, i.e. healing or major amputation was es-

tablished. Two of these patients had diabetes mellitus. The time of observation was from 1 to 6 months in five cases and 45 months in one case. These six cases are excluded from the following analysis concerning the rate of healing in relation to the distal blood pressure.

Healing Healing took place in 42 out of the 66 ulcerated feet (64 per cent). In six of these feet the healing took place after a minor amputation or resection on the foot, i.e. the limb was saved. The time to healing from the first examination averaged 5.8 months (1 to 23 months). In 24 extremities major amputation below or above the knee became necessary because of rest pains or progressive tissue destruction by ischaemia and/or infection. The time until major amputation was required averaged 4.3 months (1 to 22 months).

The systolic digital blood pressure (SDBP). The correlation between the healing rate and the SDBP as measured at the first examination in the department is shown in Figure 1 (upper panel) and Table 3. When classifying the ulcerations into three groups according to the appearance of this histogram the following healing rates are found. With SDBP of below 20 mmHg only 7 out of 24 cases healed (29 per cent). With SDBP of 20 to 29 mmHg four out of eight cases (50 per cent) healed – and with SDBP of 30 mmHg or above 31 out of 34 cases (91 per cent) healed.

During the long period of observation, however, spontaneous improvements as well as deteriorations of the arterial supply obviously took place and when relating the SDBP measured at the final examination viz. the SDBP measured just after healing or just before an inevitable major amputation, the following healing rates appear (Figure 1 lower panel, and Table 3). With SDBP below 20 mmHg only two out of 22 ulcerated feet (9 per cent) healed. In both these cases healing took place only after a minor distal amputation eliminating the low pressure tissue.

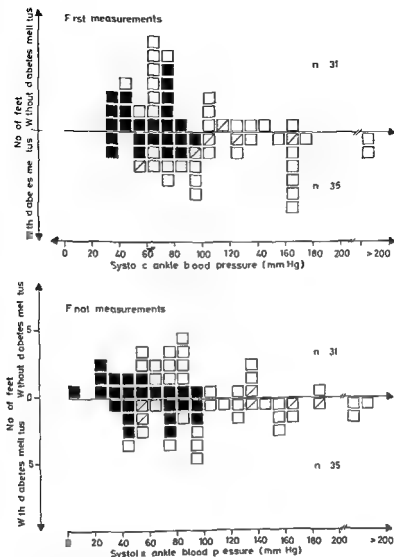
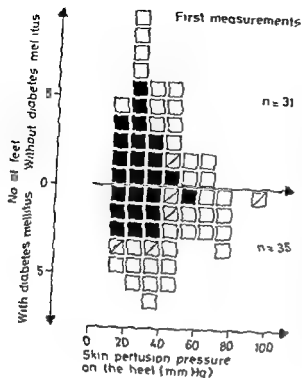


Figure 2 Healing of 66 ulcerated feet in relation to the systolic ankle blood pressure (SABP)

th SDBP of 20 to 29 mmHg 7 out of 11 cases (64 per cent) healed and with BP of 30 mmHg or above all 33 cases (100 per cent) healed. The correlations between SDBP and the healing rates are highly significant for the first measurements as well as for the final measurements ($P < 0.001$, the rank sum test).

the systolic ankle blood pressure (SABP). Figure 2 and Table 3 show the healing rates

in relation to the SABP measured at the first examination and at the final examination. The histograms show that the ulcerations can be classified into three groups with SABP below 50 mmHg, with SABP of 50 to 99 mmHg, and with SABP of 100 mmHg or more. The correlations between the healing rates and the SABP are highly significant ($P < 0.0001$, the rank sum test). There are no apparent differences between the healing rates with identical pressure range at the first and at the final measurements.



The skin perfusion pressure on the heel (SPPH) Figure 3 and Table 3 show that the

relations between the healing rates and the SPPH are highly significant ($P < 0.001$ the rank sum test)

Diabetes mellitus There was no significant difference between the healing rate in diabetic cases (25 out of 35 cases = 71 per cent) non-diabetic cases (17 out of 31 cases = 55 per cent) ($P > 0.10$, chi square test), and when comparing the total numbers or when relating the healing rates to the distal blood pressure parameters (Table 3 and Figure 1-3). The time taken for healing in our average

to 1 ($P > 0.10$, the Mann-Whitney test). Nevertheless the distal pressure parameters in the diabetic group were on average higher than in the non-diabetic group (Table 4).

The first pressure measurements were on average equal to the final pressure measurements for all three parameters (Table 4) ($P > 0.1$, the Wilcoxon test for paired comparisons). The variation with time - as expressed in standard deviations of the difference between the first and the final pressures - was greatest for the digital pressures.

Neuropathy and infection Figure 4 (upper panel) shows the distribution of peripheral neuropathy in relation to the results and the initial measurement of SDBP. Thirty-two out of 35 cases in the diabetic group (91 per cent) had peripheral neuropathy against only 8 out of 31 cases in the non-diabetic group (26 per cent) ($P < 0.001$, the chi square test). The presence of peripheral neuropathy was not correlated with the rate of amputation or with the SDBP.

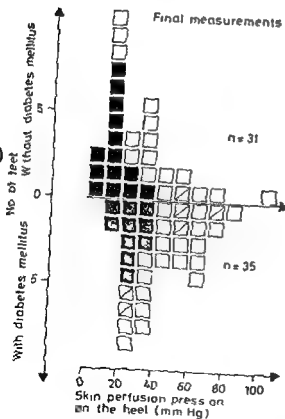
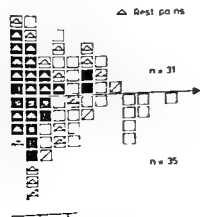
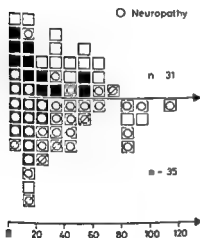
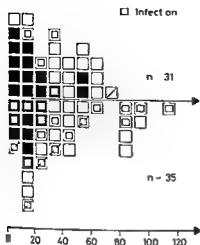


Figure 3 Healing of 66 ulcerated feet in relation to the skin perfusion pressure on the heel (SPPH)



As could be expected infection (Figure 4, intermediate panel) was also especially characteristic of the diabetic group 19 out of 35 cases (54 per cent) against 4 out of 31 cases (13 per cent) ($P < 0.001$, the chi square test) in the non-diabetic group. Infection was not correlated with the rate of amputation or with the SDBP.

Rest pains At the first examination rest pains were present in 29 feet and correlated significantly with the distal blood pressure (Figure 4, lower panel) ($P < 0.001$, the rank sum test). However, rest pains disappeared in 15 feet, i.e. in all cases that healed.

On the other hand, in 22 out of the 24 extremities which required major amputation, rest pains were the main reason for this outcome. Thus rest pains when persistent and severe are a major determinant of the result. But rest pains may be transient (15 cases) or may develop at a late stage even in the case of an ulcer in combination with a critically low digital blood pressure. This is the case in particular in diabetic cases where rest pains may even fail to develop at all.

Prognostic value of the three distal blood pressure parameters Table 5 lists the prognostic value of the initial pressures as determined by (1) risk of major amputation at low pressures, (2) chance of healing at high pressures, (3) the number of cases with intermediate pressures viz borderline values which do not indicate the prognosis. We prefer the SDBP with only a few borderline cases (12 per cent) and in particular an SDBP of above 30 mmHg indicates a good prognosis. In the two exceptions with an initial SDBP of the order 50 to 60 mmHg who required major amputation (Figure 1 upper panel) the patients sustained occlusive arterial deteriorations in spite of this high distal pressure. In one patient

Figure 4 Infection, neuropathy and rest pains at the first examination in relation to the first measurements of the systolic digital blood pressure. The symbols are added to the histogram of Figure 1 upper panel.

Table 4 The first distal blood pressures compared with final distal blood pressures and distal pressures in non-diabetics compared with distal pressures in diabetics

	First measurements			Final measurements			The difference First measurement minus final measurement		
	mean mmHg	P	range mmHg	mean mmHg	P	range mmHg	mean mmHg	SD mmHg	range mmHg
SDBP	non-diabetics (n=31)		[0 71]	29.4		[0, 117]	+1.3	21.8	[-61, 56]
	diabetics (n=35)	>0.1	[0, 117]	42.7	>0.1	[0, 118]	-2.5	21.5	[-87, 52]
SABP	non-diabetics (n=31)	<0.05	[31, 164]	75.0		[0, 187]	+4.2	26.3	[-31, 112]
	diabetics (n=33)*		[30, 248]	102.6	<0.05	[35, 243]	+2.7	17.3	[-38, 48]
SPPH	non-diabetics (n=31)		[10, 68]	30.4		[0, 110]	+1.3	12.3	[-42, 20]
	diabetics (n=35)	0.1> >0.05	[10 90]	41.3	<0.01	[16, 85]	+0.4	11.7	[-15 27]

P=P value by the Mann-Whitney test in comparing pressures in non-diabetics with pressures in diabetics. The comparison of the first and the final pressures is made by the paired Wilcoxon test. All P values were above 0.01. *The SDBP figures of diabetics are calculated for 33 cases only. In the remaining two cases it was technically impossible to record the ankle pressures which were above 300 mmHg.

Table 5 The prognostic value of the first measured SDBP SABP and SPPH

Risk of amputation at low pressure in per cent (confidence limits (95%))	No of borderline cases in per cent of whole series	Chance of healing at high pressure in per cent (confidence limits (95%))
(SDBP < 20 mmHg) 71% (49-87%)	(SDBP 20-29 mmHg) (8/66 = 12%)	(SDBP ≥ 30 mmHg) 91% (80-99%)
(SABP < 50 mmHg) 89% (55-99%)	(SABP 50-99 mmHg) (34/66 = 52%)	(SABP > 100 mmHg) 100% (85-100%)
(SPPH < 20 mmHg) 70% (35-93%)	(SPPH 20-39 mmHg) (22/66 = 44%)	(SPPH ≥ 40 mmHg) 93% (76-99%)

the occlusive event accompanied a fall in systemic blood pressure (Figure 5) and in the other patient a thromboembolic attack rendered a well nourished leg severely ischaemic. Such unpredictable occlusive events

may at any time change the prognosis for an ulceration

The SABP and the SPPH distributions contain many borderline cases although the very low as well as the very high ankle blood

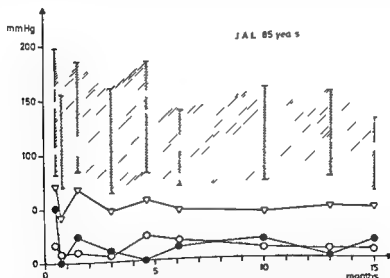


Figure 5 The measurements on a leg with ulceration of the toe in a patient aged 85 years. Filled circles: Systolic digital blood pressures. Open circles: Skin perfusion pressure on the heel. Open triangles: Systolic ankle blood pressure. Hatched area: The systemic pulse pressure as measured as the auscultatory arm blood pressure. Initially the

pressures indicate the prognosis very precisely

We also analysed the prognostic value of the combination of two out of three distal blood pressure parameters as well as of all three parameters combined. These combinations were not, however, significantly better than the SDBP.

DISCUSSION

Carter (1973) has previously published a study of the systolic digital and systolic ankle blood pressure in relation to healing of skin lesions on the feet. Using a single determination of the distal blood pressures he found that digital blood pressures of above 30 mmHg or ankle blood pressures of above 80 mmHg indicated healing of the lesions in non-diabetic patients which is in good agreement with our findings as also recently confirmed by Tønnesen et al. (in press). In Carter's series (1973) several diabetic patients, however, required major amputation even when the digital or the ankle pressures considerably exceeded the critical values found in non-diabetic patients. This is in contrast to our data which show no significant difference between the healing rates in diabetics and non-diabetics at identical distal blood pressure. This discrepancy deserves a detailed discussion.

From a methodological point of view Carter's results might suggest that distal blood pressure measurements are less reliable in diabetic patients i.e. perhaps falsely high due to mediasclerosis prohibiting proper transmission of the cuff pressure through the walls of the arteries (Nielsen & Munkgaard Rasmussen 1973; Holstein et al. 1975). Such falsely high pressures were recorded in at least two cases of our series for ankle blood pressures, viz. the arteries were not occluded by cuff pressures of 300 mmHg, the systolic arm blood pressure being 130 and 140 mmHg respectively. Direct intra-arterial blood pressure measurements, however, have shown that at the ankle level mediasclerosis is

only occasionally a source of error (Carter 1973). Our data for healing show that at the digital level mediasclerosis can not be a significant cause of erroneously high pressures.

The occurrence in Carter's series (1973) of major amputations in diabetic cases with high digital pressure might support the presumption of a haemodynamically significant diabetic microangiopathy as a cause of gangrenous skin lesions. However, recent studies (Strandness et al. 1964; Conrad 1967; 1968; Nielsen 1973) strongly argue against this hypothesis, as also pointed out by Carter (1973). Moreover, the results of our study on digital pressures do not support microvascular blocking as a haemodynamic pathogenic factor in a lesion of the diabetic foot.

Carter explained the non-ischaemic major amputations in diabetics in his series by the presence of peripheral neuropathy and infection. In our series the conservative therapy was aimed especially at the elimination of the effect of these conditions and this is probably why the healing rate in diabetics was equal to the healing rate in non-diabetics.

Finally, our cases were selected as having passed over into a subchronic phase suitable for the study of healing, i.e. the legs with the lesions had survived at least 1 month. Thus, four legs including 17 diabetic legs, undergoing major amputation during the first month were thus excluded from our series. These cases were severely ischaemic except for one case, a diabetic leg with normal distal pressures but with a septic inflammation in the calf originating from a plantar abscess. Adequate therapy was initiated too late and a below-knee amputation was made. This case illustrates that diabetic lesions may lead to major amputation in spite of adequate blood supply, if treatment is delayed or inadequate.

Oakley (1954) classified diabetic foot lesions as ischaemic, septic, neuropathic or due to a combination of these causes. This classification gives the key to the proper therapy and should replace the non-specific term 'diabetic gangrene' which is still commonly used. At present Oakley's

classification is more useful than ever because ischaemia can be defined objectively by measurement of the distal blood pressure. If the local blood pressure is too low for healing of a lesion revascularization must be considered. In this instance it should be emphasized that patients with digital blood pressures of below 20 mmHg but without skin lesions and without rest pains are not uncommon. However, if a traumatic skin lesion occurs or if gangrene develops the leg is threatened. We therefore also consider these patients as potential candidates for vascular surgery.

The three parameters studied were all significantly correlated with healing. The SDBP being valuable in the diagnosis of the arterial occlusion is, however, less helpful in judging the prognosis. The figures for healing in relation to the SDBP and SPPH agree with previous studies on wound healing after major amputation (Holstein 1973, Holstein et al. 1979 a, b) and the SDBP is particularly valuable. On the basis of our initial pressure measurements in combination with the final pressure measurements we feel justified in concluding that when the digital blood pressure lies constantly below 20 mmHg healing of an ulcer will only rarely take place whereas at digital pressures of above 30 mmHg ischaemia is not a problem in wound healing.

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MECHANICS OF THE HALLUX VALGUS FOOT AND THE EFFECT OF KELLER'S OPERATION

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Using a system for measuring the load distribution under the foot, patients with hallux valgus were compared, before and after undergoing Keller's operation, with a group of normal subjects. Preoperatively the patients showed reduced loading under all their toes and increased loading under their lateral metatarsal heads, the decrease under the hallux was found to correlate with an increase in hallux valgus angle. Postoperatively there was a further decrease in loading under the hallux and an increase under the first metatarsal head.

Key words hallux valgus, Keller's operation, load distribution

Accepted 24 iii 80

There are many factors which contribute to the aetiology of hallux valgus. The full range has been reviewed extensively (Hardy & Clapham 1952, Kelikian 1965, Du Vries 1973, Edgar 1976). There are three basic types of operations that are performed to correct hallux valgus: osteotomy, arthrodesis and arthroplasty, of which there are numerous variations. However, the excision arthroplasty of the proximal phalanx described by Keller (1904) and earlier by Davies-Colley (1887) is possibly the most commonly used.

In normal walking the medial side of the forefoot is heavily loaded with the hallux carrying about twice as much load as the other toes combined and about the same as the first metatarsal head (Hutton & Dhanendran 1979). It was thus felt relevant to compare the loading pattern under the hallux valgus foot with that under the normal foot and correlate any differences with the severity of the deformity. To complete the comparison it was of interest to compare the loading pattern obtained from the patients before and after Keller's operation.

It is hoped that the results presented here will better explain the progressive changes occurring with hallux valgus and allow treatment to be planned accordingly.

SUBJECTS STUDIED

Sixty-five feet from thirty-four female patients with hallux valgus were studied. Their mean weight was 59.1 kg and their ages ranged from 16 years to 78 years with a mean of 46.8 years. Thirty-one patients had bilateral hallux valgus. The three normal feet of the patients with unilateral hallux valgus were not included in this study.

The results were compared with those from sixty-four normal feet of thirty-two females with no previous history of foot or gait abnormalities. Their mean weight was 59.3 kg and their ages ranged from 15 years to 66 years with a mean of 40.7 years. They all had full foot and ankle movements. None of them had ever sought treatment for their feet and none had toe deformities or painful callosities.

Eleven of the thirty-four patients were measured about a year after a Keller procedure. In five of these patients only one foot was operated

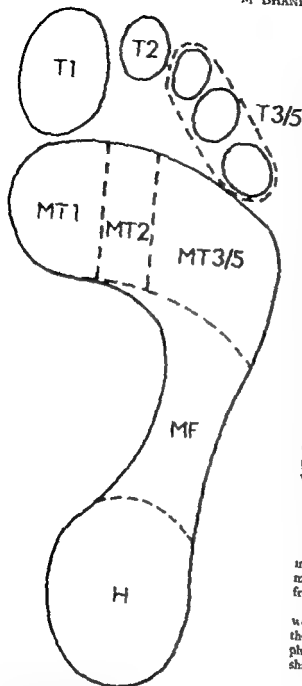


Figure 1 The eight areas of the foot

on, making a total of 17 feet for comparison before and after surgery. Their ages ranged from 51 to 78 years with a mean of 63.3 years.

METHOD

The distribution of vertical load under the feet of the patients and the normal subjects was

measured using a system of 128 strain load cells connected to a minicomputer storage and processing. The load cells were packed in a 16×8 matrix giving an overall sensitive surface of 25 by 12.5 cm. The details of the system have been described elsewhere (Dhanendran et al. 1978).

The load cell matrix was set in an 8:1 walkway upon which subjects walked barefoot at their normal walking speed. Their foot position was adjusted so that the required load was on the load sensitive surface without any distortion to their normal gait. A piece of paper with the outline of the load cells printed on it was sandwiched between a cloth sheet and the load cells. The cloth sheet had a water-proof surface and its under surface was coated with printer's ink so that when a subject stepped on the load cells an inked impression of the foot in the correct register, was printed on the sheet of paper. The upper surface of the cloth sheet was painted the same colour as the walkway so that the subject was unaware of the exact location of the load cells.

For ease of analysis the foot was divided into eight areas as shown in Figure 1. For each area the force against time waveform was stored on each load cell. From this the force waveform for each area of the foot was computed. The parameters were extracted from the waveforms:

1. The peak force in each area normalized for the subject's body weight.
2. The contact time for each area, normalized for the contact time for the entire foot.

For convenience, the three lateral toes were included together as were the three lateral metatarsal heads. The means of the measurements from four walks were computed for each foot.

The hallux valgus angle was measured from weight-bearing radiographs. This was defined as the angle between the long axes of the proximal phalanx of the hallux and the first metatarsal shaft.

RESULTS

Comparison between the normal groups of subjects and the preoperative group of patients

The means of the peak force and contact time parameters for the 65 feet with hallux valgus are compared with the means for the 64

Table 1 The mean values of the peak forces for normal and hallux feet. Significant differences between the means are indicated (*—1 per cent, **—5 per cent, Mann Whitney Test)

	Peak Force							t
	T1	T2	T3/5	MT1	MT2	MT3/5	MF	
normal feet	17.8	3.2	5.2	25.3	24.3	20.9	12	
hallux valgus feet	11.1**	2.3**	4.8*	26.5	26.0	41.5**	11.9	4.6 4.6

Table 2 The mean values of the contact times for normal and hallux feet

	Contact Time							t
	T1	T2	T3/5	MT1	MT2	MT3/5	MF	
normal feet	56.2	26.1	38.7	80.8	81.3	81.3	4.3	
hallux valgus feet	43.4**	24.3	34.4	80.5	82.1**	81.3	4.3	4.6 4.6

normal feet in Tables 1 and 2. The Mann Whitney statistical test was used for the comparison and only results significant at the 5 per cent level or better will be discussed.

In the hallux valgus feet the first and second toes carried less load while the lateral three metatarsal heads carried more load. The contact time showed a similar trend with a reduction for the hallux and increases for the

lateral three metatarsal heads and the heel.

Comparison with the normal feet of patients

There was no significant difference between the hallux feet of patients and the normal feet of patients ($P = 0.1$ per cent).

Table 3 The mean values of the peak forces for the pre- and postoperative hallux valgus feet

	Peak Force							
	T1	T2	T3/5	MT1	MT2	MT3/5	MF	H
Preoperative feet	7.7	2.1	5.4	27.4	26.9	41.9	12.4	63.8
Postoperative feet	2.5**	1.3	3.6	33.3*	29.4	38.9	11.7	39.2

second toe also showed a significant negative correlation in load ($P = 1$ per cent) with the hallux valgus angle.

Comparison between the preoperative and the postoperative group of patients

Tables 3 and 4 show the mean values of the peak force and contact time parameters measured for the 17 feet pre- and postoperatively. The only differences postoperatively were a further reduction in hallux loading, an increase in loading under the first metatarsal head and a further decrease in contact time for all the toes.

DISCUSSION

As compared to the normal group, the preoperative group of patients showed a reduction in loading and contact time under the hallux and a reduction in loading under the second toe. The reduction under the second toe, although statistically significant, should not affect foot function to any great extent because it carries only a small percentage of the body weight. This reduction in loading may have been caused by the displaced hallux crowding the second toe and thus preventing sufficient activity of the plantar flexors.

The activity of the short and long flexors of the hallux determines the degree of at kick-off. The sesamoids are incorporated into the tendons of the flexor hallucis brevis as they pass under the metatarsal head while the flexor hallucis longus tendon passes between the two branches of the flexor hallucis brevis. The valgus deformity of the hallux is usually accompanied by a rotation so that the medial border moves downwards (everts). Additionally, the sesamoids slip their position beneath the metatarsal head, moving laterally relative to the metatarsal head. This means that the long and short flexors no longer act as true flexors but more as adductors of the hallux (Kehkian 1965). This impairment in function can account for the reduction of hallux loading with any suffering of the metatarsophalangeal joint due to arthritic changes being an additional compounding factor.

The preoperative group of patients had higher than normal loading under the lateral metatarsal heads, probably as a result of a re-adjustment of their walking pattern over a long period of time. This could be the result of an effort to protect the affected medial side by reducing the amount of pronation that occurs in the early phase of foot contact (Hutton et al 1976). Kaplan (1955) found, in routinely dissected feet, that those with

Table 4 The mean values of the contact times for the pre- and postoperative hallux valgus feet

	Contact Time							
	T1	T2	T3/5	MT1	MT2	MT3/5	MF	H
Preoperative feet	35.2	26.7	43.7	79.5	86.8	91.4	56.5	57.4
Postoperative feet	7.9**	9.2**	28.5*	75.4	81.9	86.2	49.4	53.9

hallux valgus showed a thickening of the tendon of the tibialis posterior muscle which is the strongest inverter of the foot

A comparison of the contact time parameters showed that patients with hallux valgus spent a longer percentage of time on their heel, midfoot and lateral three metatarsal heads in comparison to the normal subjects. This could be the mechanism by which they compensate for the shorter duration of loading on all their toes. This is further evidence of an alteration in their gait pattern. Postoperatively the contact time of the toes was further reduced while none of the other areas showed a significant change. This suggests that the reduction in hallux function effectively means a reduction in function for all the toes.

Preoperatively, the significant correlation between hallux loading and hallux valgus angle suggests that patients showing lower values of hallux valgus angle carry higher loads under the hallux. Therefore Keller's operation, which tends to de-function the first metatarsophalangeal joint and the hallux, has a highly detrimental effect on these patients. Furthermore, Keller's operation results in a corresponding increase in load on the first metatarsal head. What is the effect of this?

First let us consider normal feet during walking. In the early phase of foot contact, when the heel and forefoot are simultaneously load bearing, the longitudinal arch of the foot is supported in part by the bones being in mutual compression, like a masonry arch, and in part by the plantar ligaments and the long flexor muscles. In the latter phase of foot contact, when the heel and midfoot are no longer load bearing, the plantar aponeurosis braces the longitudinal arch through the windlass mechanism (Hicks 1954). This effect is more pronounced on the medial side of the foot since the radius around the first metatarsophalangeal joint is greater. At this phase of foot contact the loads acting across the metatarsophalangeal joints and on the metatarsals reach a maximum (Stokes et al 1979). Assisting the supporting action of the plantar aponeurosis on the longitudinal arch

is the load carrying ability of the toes since this ligament attaches onto the proximal phalanges.

In hallux valgus, and even more so after Keller's operation, the two medial toes carry less load and thus the bracing of the longitudinal arch by the plantar aponeurosis is reduced. This has the effect of increasing the stress on the plantar ligaments at the base of the metatarsals. Furthermore, any increase in load taken by the metatarsal heads, as occurs after Keller's operation, aggravates this situation.

CONCLUSION

Patients with hallux valgus show reduced loading under all their toes and increased loading under their lateral metatarsal heads. After Keller's operation there is a further decrease in loading under the hallux and an increase under the first metatarsal head. The results also suggest that the hallux valgus angle could be used to assess the load bearing ability of the great toe.

ACKNOWLEDGEMENTS

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ANNOUNCEMENTS

POSTGRADUATE SEMINAR ON BONE PATHOLOGY AND CLINICAL MANAGEMENT

A postgraduate seminar on *Bone Pathology and Clinical Management* will be held in Nijmegen, The Netherlands, from June 15-19, 1981.

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In Vol 51, pp 429-437 "*Mechanical Property Distributions in the Cancellous Bone of the Human Proximal Femur*" the MN/m² modulus and yield strength values were erroneously inflated by a factor of ten

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